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THIRD CONVENTION

OF

WEATHER BUREAU OFFICIALS

HELD AT

PEORIA, ILL., SEPTEMBER 20, 21, 22, 1904.

Published by authority of
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under direction of
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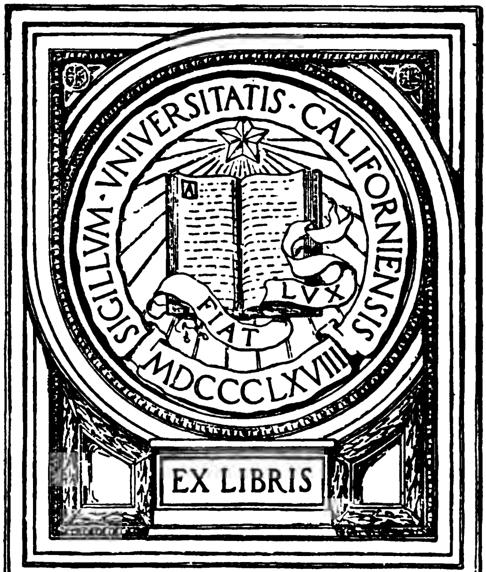

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PROCEEDINGS

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CONVENTION ORGANIZATION.

President:

Prof. Willis L. Moore.

Vice-presidents:

Prof. Cleveland Abbe.
Mr. E. A. Beals.
Prof. H. J. Cox.
Prof. E. B. Garriott.
Prof. A. J. Henry.
Prof. Alex. G. McAdie.

Secretary:

Mr. James Berry.

Committee on arrangements:

Dr. W. F. R. Phillips.
Mr. James Berry.
Mr. E. B. Calvert.

Recorder:

Mr. R. M. Reese.

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LETTER OF TRANSMITTAL.

United States Department of Agriculture,
Weather Bureau,
Washington, October 31, 1904.

The honorable Secretary of Agriculture,
Washington, D. C.

Sir: I have the honor to transmit herewith the report of the third convention of Weather Bureau officials, held at Peoria, Ill., September 20, 21, 22, 1904, with request that it be published as a bulletin of the Weather Bureau.

The reports of previous conventions have proved valuable, more particularly those of the Omaha and Milwaukee meetings. The convention recently held at Peoria was very successful, and the report of its proceedings will be of interest and practical value, not only to the officials of the Weather Bureau, but to students of meteorology in this and other countries. An edition of 5,000 copies is recommended.

Very respectfully,

Willis L. Moore,
Chief United States Weather Bureau.

Approved:
James Wilson,
Secretary of Agriculture.

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PROCEEDINGS OF THE THIRD CONVENTION OF WEATHER BUREAU OFFICIALS.

MINUTES.

The third triennial convention of Weather Bureau officials was held in the auditorium of the Bradley Polytechnic Institute, at Peoria, Ill., September 20–22, 1904.

While the membership of the convention was smaller than that of the one held at Milwaukee in 1901, its work was not less extensive, and entailed upon those present a larger share and more general participation in its labors than fell to the lot of those attending the Milwaukee meeting.

The following members were present:

Cleveland Abbe, Washington.
W. H. Alexander, Galveston.
R. G. Allen, Ithaca.
H. C. Bate, Nashville.
J. L. Bartlett, Madison.
J. W. Bauer, Columbia, S. C.
E. A. Beals, Portland, Oreg.
W. S. Belden, Vicksburg.
James Berry, Washington.
F. H. Bigelow, Washington.
W. T. Blythe, Indianapolis.
E. H. Bowie, St. Louis.
F. H. Brandenburg, Denver.
B. Bunnemeyer, Providence.
W. G. Burns, Springfield, Ill.
E. B. Calvert, Washington.
F. A. Carpenter, San Diego.
F. P. Chaffee, Montgomery.
G. M. Chappel, Des Moines.
I. M. Cline, New Orleans.
H. J. Cox, Chicago.
D. Cuthbertson, Buffalo.
E. H. Emery, New York.
E. A. Evans, Richmond.
O. L. Fassig, Baltimore.
E. B. Garriott, Washington.
S. W. Glenn, Huron.
R. B. Harkness, Houghton.
A. J. Henry, Washington.
T. B. Jennings, Topeka.
J. Kenealy, Cleveland.
H. H. Kimball, Washington.
C. E. Linney, Santa Fe.
G. A. Loveland, Lincoln.
J. B. Marbury, Atlanta.
C. F. Marvin, Washington.
A. G. McAdie, San Francisco.
A. J. Mitchell, Jacksonville.
W. L. Moore, Washington.
G. R. Oberholzer, Charlotte.
T. S. Outram, Minneapolis.
W. S. Palmer, Cheyenne.
W. F. R. Phillips, Washington.
George Reeder, Columbia, Mo.
R. M. Reese, Washington.
H. W. Richardson, Duluth.
F. Ridgway, Pittsburg.
G. N. Salisbury, Seattle.
J. H. Scarr, Sacramento.
D. A. Seeley, Chicago.
J. M. Sherier, Davenport.
J. W. Smith, Boston.
J. H. Spencer, St. Louis.
J. Warren Smith, Columbus.
P. H. Smyth, Cairo.
R. H. Sullivan, Grand Junction.
L. M. Tarr, New Haven.
A. H. Thiessen, Washington.
C. D. C. Thompson, Detroit.
T. F. Townsend, Philadelphia.
J. R. Weeks, Macon.
E. L. Wells, Boise.
W. M. Wilson, Milwaukee.

President Willis L. Moore, Chief United States Weather Bureau, called the convention to order at 10 a. m., 20th, and after the roll call by the secretary delivered the opening address, which is printed in full elsewhere.

The following resolution was offered by John W. Smith, district forecaster for New England:

That this convention of Weather Bureau officials tenders its greetings to the Hon. James Wilson, Secretary of Agriculture, and expresses its appreciation for the great development of the Weather Service under his administration.

In connection with the foregoing resolution Professor Moore stated:

Before I put that to vote I would say a word in regard to the relation of the Secretary to this Bureau. As you all know he takes a great interest in our work. He has encouraged me, and everyone associated with me, to go forward. I have never brought to him a proposal that had for its object the extension of the Weather Service, the improvement of any line of its work, or the promotion of any deserving official that did not receive his warm commendation. So we have a great deal to be thankful for in the fact that such a man as James Wilson is Secretary of Agriculture. In putting the motion I ask that it be a rising vote.

Adopted unanimously by rising vote.

The above resolution was telegraphed to the honorable Secretary of Agriculture, who replied as follows:

UNITED STATES DEPARTMENT OF AGRICULTURE,
Washington, D. C., September 21, 1904.

Hon. WILLIS L. MOORE, *Peoria, Ill.:*

Greeting to gentlemen of the Weather Bureau. You are systematically reducing to an exact science the facts regarding meteorology for the benefit of agriculture, commerce, and navigation. Upon the foundations laid a superstructure is being erected that will bless mankind and be creditable to American research. It is an honor to be associated with you.

JAMES WILSON, *Secretary.*

Prof. A. G. McAdie read a paper on "Laboratory work in meteorology."

Prof. F. H. Bigelow read a paper on "The Mount Weather Research Observatory," at the conclusion of which there was a symposium on the purposes of the Mount Weather Research Observatory, in which the following-named gentlemen participated: Profs. W. L. Moore, C. Abbe, and C. F. Marvin, Dr. O. L. Fassig, and Messrs. L. M. Tarr, J. Warren Smith, F. P. Chaffee, G. A. Loveland, and T. B. Jennings.

Prof. C. F. Marvin read a paper on "Errors of instruments and the lines along which improvements should be sought."

Mr. G. R. Oberholzer exhibited and explained a shading device of his own invention for use in connection with the sunshine recorder.

Prof. E. B. Garriott read a paper on "Long range weather forecasts," which concluded the first session.

The convention met at 3.05 p. m., 20th, Professor Moore in the chair, and resumed its work by a discussion of the subject of "Long range weather forecasts," the last paper of the first session, the following-named gentlemen taking part: Profs. W. L. Moore and H. J. Cox, and Messrs. J. Warren Smith, James Berry, W. T. Blythe, G. M. Chappel, T. B. Jennings, I. M. Cline, J. B. Marbury, J. W. Bauer, and A. J. Mitchell.

Prof. A. G. McAdie read a paper on "Seasonal forecasts."

Dr. W. M. Wilson read a paper on "Amplification of forecasts for the benefit of perishable products;" discussed by Professors Moore and Abbe.

Mr. F. H. Brandenburg read a paper on "An aid in forecasting."

Prof. H. J. Cox submitted the report of the board on revision of meteorological forms; and questions in connection therewith, by Messrs. Chaffee, Emery, and Scarr, were answered by Professors Cox and Henry, members of the board; remarks by Professors Moore, Marvin, and McAdie and Messrs. Berry, Sullivan, Blythe, and Seeley.

A paper on "Forecasting fogs on the Gulf coast" was read by Mr. B. Bunnemeyer.

On account of the lateness of the hour and the impossibility of reading in the time available Professor Bigelow's paper entitled "A popular account of the countercurrent theory of storms," its postponement until the following morning was agreed to, and Mr. H. H. Kimball proceeded with his paper on "Variations in insolation and in the polarization of blue sky light during 1903 and 1904."

The third session of the convention was called to order by Prof. Cleveland Abbe at 10.10 a. m., 21st.

Prof. F. H. Bigelow read the postponed paper referred to in the minutes of the second session; remarks by Professor McAdie, Mr. Salisbury, Professor Abbe, and Mr. Mitchell.

Mr. E. H. Bowie read a paper on "A possible method for determining the direction and velocity of storm movement;" remarks by Mr. Chaffee and Professor Moore.

Mr. E. B. Calvert asked and was granted the privilege of stating that there had been presented to the convention by horticulturists of Colorado and California, in recognition of the value to them of the special warnings of the Weather Bureau, several cases of very fine fruit, consisting of apples, peaches, and olives.

Mr. W. H. Richardson read a paper on "Temperature forecasts and iron-ore shipments;" remarks by Professor Moore.

Mr. G. M. Chappel read a paper on "Distribution of forecasts by telephone;" discussion by Messrs. W. G. Burns and J. Warren Smith.

Mr. P. H. Smyth read a paper on "Practical rules for forecasting flood-crest stages for Cairo, Ill."

A paper entitled "The Columbia River" was read by Mr. E. A. Beals, and one entitled "Diurnal periodicities in the climate of Baltimore" was read by Dr. O. L. Fassig.

The fourth and last session of the convention was called to order at 9 a. m., 22d; Prof. E. B. Garriott in the chair.

Mr. J. Warren Smith read a paper entitled "Phenological observations at Wauseon, Ohio;" discussed by Messrs. Scarr and Jennings, and Professor Abbe.

Mr. B. Bunnemeyer read a paper on "A study of rainfall on the west Florida coast;" discussed by Messrs. Mitchell and Bate, Professor Garriott, and Mr. Bauer.

Mr. W. H. Alexander read a paper on the "Climatology of Porto Rico." Remarks by Professors Abbe and Henry.

A paper entitled "Monthly statement of averages for rural press" was read by Mr. W. S. Belden. Discussed by Messrs. J. Warren Smith and T. B. Jennings, Professors Abbe and Moore, Doctor Fassig, and Professor Henry.

Dr. I. M. Cline read a paper on "Irregularities in frost and temperature in neighboring localities." Discussed by Messrs. Mitchell and Seeley.

Mr. James Berry read a paper entitled "Former conventions of Weather Bureau officials."

Professor McAdie moved that the convention offer a vote of thanks to the committee on arrangements "for the great work they had accomplished in carrying out the plans for the convention." In seconding the motion Professor Moore stated:

> This is unquestionably the most successful convention we have ever had. I have had little to do with it. Doctor Phillips, Mr. Berry, and Mr. Calvert have arranged all the details, and it has been a long work to do all the things necessary to bring these gentlemen here and work up to such a splendid culmination as this convention has attained.

The motion was adopted unanimously.

Mr. Beals offered a resolution of thanks to the officers of the Bradley Institute for the use of their hall. Adopted.

Prof. R. F. Stupart, director of the Canadian meteorological service, upon being introduced, said:

> I wish to say how thoroughly I have enjoyed the very few moments I have been privileged to spend with the Weather Bureau officials, and should it be determined that the next convention be held on the east side of the Mississippi River, I hope that convention may be held in Toronto. As director of the Canadian meteorological service, I extend to you a cordial invitation to hold the next Weather Bureau convention in Toronto or Ottawa, as the case may be.

The convention was brought to a close by the following statement by Professor Moore:

> I want to express my own deep gratification at the loyal assistance that I received, not only from members of this convention, but from all associated with me in this work of the Weather Bureau. If it is successful it is because very able men give to the service the best that is in them; and I would say also that I strive to get the confidence of the President of the United States, of the Secretary of Agriculture, and of the committees in Congress in our integrity of purpose, and to convince them of the value and utility of this service. Above all things, I want to say that I am deeply impressed by the confidence and good will of those associated with me.
>
> As this convention opened in the name of our respected and beloved Secretary, so does it close in his name.

The convention then, at 11.05 a. m. of the 22d, adjourned sine die.

The convention committee desires to acknowledge its indebtedness to Mr. R. M. Reese, stenographer to the honorable Secretary of Agriculture, for the satisfactory manner in which the proceedings of the meeting were recorded, and to Mr. Edward C. Easton, of the Climate and Crop Division of the Weather Bureau, for his assistance in the preparation of the report.

FIRST SESSION.

PRESIDENT'S ADDRESS.

Prof. Willis L. Moore, *Washington, D. C.*

Gentlemen of the Convention: I have not had much to do with the organization of this convention. That has been left to a committee consisting of Doctor Phillips (who, I am sorry to say, is no longer connected with the Bureau), Mr. Berry, and Mr. Calvert. Doctor Phillips has left us because he has been called to a more important work. He is dean of the college of medicine in the new George Washington University, of Washington, formerly the Columbian University. I feel that it is a compliment to the Weather Service that one of our officials should be called to such an important post. He was a loyal and efficient assistant to the head of the Weather Service, and, while I am glad that he has been advanced, we all regret that he is no longer one of us.

The committee has put me down for an address. I am like the man who had no dinner and no money to buy a dinner—I have no address, and I am sure I hardly know where one would come from. I may talk to you for a few moments, but I will try not to do what people often do when they have no speech—talk on and on forever.

Our last convention, as you know, was at Milwaukee. It was fruitful in good results. Much of the discussion that took place at that convention and the ideas that were brought out were finally matured into the results that have been accomplished in the last three years. This is a sort of clearing house for meteorological ideas. Here is where we come together from all quarters of the country, each one of you an expert in this particular line of work, each one with a certain personal knowledge of how the meteorological service can be made useful to the industries of his community. You bring that knowledge here. You impart it the one to the other. Each man brings something and takes away a great deal. I know that I take away from these conventions a great deal more than I bring. We have for the last three years seen a better correlation of the work of the local forecaster and the district forecaster, so that there may be proper adjudication of authority between them. Only time and experience could work out that problem, so that the great property and industrial interests that we are created to serve might get the best expression of opinion we are able to give as to the coming weather. And now we have each forecaster working in competition one with another, in which the fittest survives. It may be a little hard for some of you, but it is best for the public service. We have seen the flood service vastly extended, especially by recent act of Congress, as a result of the demonstrated utilities of the flood service to the commercial interests of the great interior rivers. We have learned from the people themselves that they want a knowledge of gage readings and of coming water stages even in the small rivers. And so, as a result of the discussion that took place last winter before the Committees on Agriculture in Congress, we received the money largely to extend the river service. Doctor Frankenfield has traveled extensively, under the general direction of Professor Garriott, in organizing the flood service on rivers that before we thought had not enough industries adjacent thereto to justify the expenditure.

Our climate and crop service, under Mr. Berry's able administration, has been greatly strengthened and extended, and for some years past, we may say, has commended itself to the confidence of the great commercial exchanges and of the farmer in the integrity of the weekly crop report. There are times when the weekly crop report, like the morning forecast, is the controlling factor in determining the price of farm products. It is necessary that our crop reports and our weather forecasts should be like Cæsar's wife—above suspicion. Our officials can not afford to be speculators; they can not afford to have any pecuniary interest in the price of a commodity that their crop reports and forecasts may directly or indirectly affect. And they do not have. Weather Bureau officials must remain poor and honest. And I am proud to feel that they are honest, and I know that the commercial organizations of the country and the farmers are satisfied that our reports are honest, are the best expression of opinion we can give, and that our minds are free from bias. So we see this climate and crop service developed very much as the result of the discussions of our work at our last convention.

Now, it seems as though we had developed the utilities of the meteorological service, I will not say as far as they may be developed, but we have brought them at least to such a state of efficiency as to meet the commendations of those we are created to serve. And then comes to our mind the fact, as brought out at our last convention, that while we have learned how to apply our limited knowledge more advantageously to the country we have not made substantial progress in the science of meteorology. Now, the next step is to add to our knowledge; to do something to develop the scientific side of the meteorological service. We can not hope for that development to come from the outside. There is no institution that is equipped to train scientific men as this institution is. So, as I promised you three years ago, we are now beginning to do something to add to our knowledge of the mechanics of storms, and at Mount Weather, Virginia, we are building quite an elaborate research observatory, or rather several observatories under one head, in which it is our purpose to group all of the lines of research that have, directly or indirectly, a bearing upon meteorology. We trust that we shall be able to create an institution there that for pure science shall do as much for the good name and fame of the United States Weather Bureau as has resulted from our forecasting service and our climate and crop service. We will take up the discussion of that a little more fully later on. It is a subject I am much interested in. Secretary Wilson has given much thought to it and has encouraged us to get the best appliances and utilize the highest talent in that research institution.

We have in the past three years strengthened and improved the discipline of the service, with the object of bringing forward fairly and impartially those best fitted to the service, and in some cases dropping back those less fitted. That discipline we try to make fair, although rigid. Recently you have observed that there have been several reductions as a result of growing inefficiency due to old age. That may require a word of explanation, for I would not wish some of you, who are getting on the shadowy side of life, but are just as strong mentally and more valuable to the public service than you ever were before, to feel that we purpose to make age alone the measure of a man's efficiency. Some men are better at 70 than they were at 40. So I simply wish to emphasize the fact that age alone is not the measure of a man's efficiency.

We have a number of guests present, and I am particularly pleased to see a number of ladies present. I am more than pleased to see our good friend, Father Odenbach. He takes a great interest in the work as an independent investigator, and I know you are pleased to see his good face here to-day. [Applause.]

I feel like talking a long time to you, but we have a programme and I have no speech. So we will come to the first paper—Professor McAdie's, on "Laboratory work in meteorology." But first let me say that you are all familiar with the report Professor McAdie has written on the climatology of California—a State that has such a wonderfully diversified climate, and in which there are so many diversified industries that the study of its climate is very valuable to its economics. While his report is not so complete as to shut out future discussion and compilation of data, it is very creditable to the service and to him, as his whole work on the Pacific coast has been.

LABORATORY WORK IN METEOROLOGY.

By Prof. ALEXANDER G. MCADIE, *San Francisco, Cal.*

Some years ago, in reply to a letter urging the need of courses in meteorology, a kind answer came back from the president of the university favoring action for several reasons, one of which was that the meteorologist has all-out-of-doors for a laboratory.

To-day laboratories are essential in all courses pertaining to the applied sciences. That meteorology is one of the applied sciences needs no argument. Indeed, if the work which our countryman, Carl Barus, is engaged upon—nucleation and condensation in the free air—be carried to a finish, meteorology may become the most important of the applied sciences.

To some degree our colleges and universities are gaged by the completeness and thoroughness of their laboratory equipments. Men rightly give the preference to that university which offers the greatest facilities for research work in the line of their choice. What, then, should be the ideal equipment for laboratory work in meteorology? Surely something more than the opportunity to chart and study weather maps, or the privilege of handling ordinary station equipment and the keeping of individual records. All of these a student may do faithfully with some profit and pleasure to himself; but without contributing (and this is of much more importance) his just portion, however small individual contributions may seem to be, to the advancement of knowledge for the betterment of mankind. Too much routine work in recording data may unduly magnify the record at the expense of the observer. Unfortunately there is much in our forms and literature which needs clearer expression. It is a wise man who can without hesitation define some of the terms which are in common use, and even in the expression of air movement one must first ask, "In what sense does the writer employ this term?" Again, back of every observation there is a physical process operative; but this the student too often loses sight of. In other words, the moment the observation is jotted down the forces at work are forgotten. Is this not the reason why so many intelligent science teachers to-day fail to realize the importance of meteorology? I had an experience emphasizing this point last summer. Traveling in company with many botanists, geologists, and nature lovers we journeyed day after day through the forests on the flanks of the Sierra. The foresters told us about the life histories of sequoia, yellow pine, sugar pine, tamarack, and all of the mountain trees; the botanists brought to notice every wild flower met with, and the geologists were busy discussing hanging valleys, glacial markings, and evidences of this or that action. There seemed to be no call for the meteorologist except to give appropriate elevations by barometer. One day above the Kaweah peaks there appeared a small cirro-cumulus cloud. It was the first cloud we had seen since leaving the foothills. There was some comment about its beauty, and then a well-known geologist, mechanical engineer, map maker, and all-around man of science said with some contempt: "What good is a cloud? You can't go to it." The meteorologist found his tongue: "You do not have to go to it. Unlike the forest, the flowers, and the mountains the clouds come to you. They are the real travelers of earth." He tried to tell them something about water vapor and its restless journeying from the level of the sea to the level of the upper cloud. To the lovers of trees it was pointed out that the summed-up history of each season's sunshine and rainfall might be decipherable in the rings of annual growth, and that the set of the branches and twigs might indicate prevailing wind direction. To the geologists it was shown that the loftiest peak in sight did not equal in size some of the clouds; that Whitney might be piled on top of Whitney and still fall short of equaling some massive cumulo-nimbus clouds. The granite cliffs in sight doubtless changed slowly; but it was within the power of a cloudburst to alter in a few hours the whole aspect of the cliff. A mountain lake whose origin was a subject of dispute was probably made by a landslide, which in turn was due to phenomenally heavy rains; and later, the date of the occurrence, January, 1862, was confirmed by rainfall records. Even glacial markings are in one sense meteorological records, and when the meteorologist comes to study the evolution of climate he will develop much that will be serviceable to the geologist. For the special benefit of the mechanical engineer it was pointed out that in so simple a matter as cloud building there was exemplified in operation the most powerful lever modern civilization has yet made use of, viz, the expansive power of water vapor.

To most of those present it had not previously occurred that meteorology could bear so directly upon problems in their allied fields. And it was something of a surprise to them to realize how much out-of-door work was demanded of the meteorologist.

The movements of the air on a large scale are not the only ones of interest to the meteorologist. The motion of the air in a storm is not more deserving of study than the air motion in many local circulations, most of which we seldom think about. There is a very interesting circulation of water in a drop of dew. Insert a flake of lycopodium powder on the end of a needle into a drop of dew, hold the latter at a proper angle to the sun, and you will see the speck whirl round and round the equator of the drop until the drop itself is evaporated. That most commonplace thing, a drop of rain, is a microcosm of scientific interest. Calculate the energy required to evaporate the water, consider how and where heat was given off when the vapor condensed, how much energy due to the mass and motion of the drop was transformed when the drop hit the pavement. Or, to go back further, what was the energy of chemical combination when the oxygen and hydrogen came together; or, still more interesting, what part did the ions and electrons play in bringing about a condition under which the condensed vapor globule became a falling raindrop, or a snowflake, or a frost crystal?

These are the experiments going on daily in Nature's laboratory, and if our young college men could have their interest aroused and the desire kindled within them to know more of these seemingly simple occurrences, there would be less occasion at commencement exercises to exclaim with the Oxford professor concerning the honor men: "Never mind, they will do good work in life as soon as they recover from the effects of their education."

To-day it is almost beyond the comprehension of most of us that there can be such infinitesimally small bodies as electrons, and we can only vaguely follow the excursions and vagaries of these smallest of the small fry. But then only two hundred and fifty years ago men could form no conception of physical properties of air, which to-day everyone easily recognizes. Even the inventor of the air pump, Otto von Guericke, thought that air was an exhalation or odor given off by bodies. Galileo probably did not understand that air exerted pressure. His secretary and pupil, Torricelli, did, and he was probably the first man to clearly understand this problem. To us it is easy of comprehension; to the investigators of the seventeenth century it was most difficult. And in turn, if the laboratory work which the present condition of the science demands be properly performed, our successors will have clear conceptions of processes of far-reaching importance in meteorology now all unknown to us.

A very partial and incomplete list of subjects awaiting investigators, follows: (1) The formation of rain; nucleation; condensation; (2) radio-active properties of air; (3) atmospheric electricity; (4) photomicrography; (5) aberration of sound waves in air; (6) atmidometry; (7) analogues of vortices.

DISCUSSION.

J. Warren Smith. To emphasize the argument of Professor McAdie as to the value of laboratory equipment, as well as for the benefit of those present who are teaching this subject, I wish to explain an experiment which I once assisted in performing and preparing while with Prof. W. M. Davis at Cambridge.

A large copper tub about 3 feet across was procured and arranged so that it could be turned around rapidly. It had a jacket on the outside in which was placed hot water or steam, and an inside core into which was placed cracked ice. Then two gases were let into the tub, the combination of which would make a visible gas or vapor. A large glass cover was placed on the tub, so that the movements of the vapor could be easily seen.

Air currents were immediately set up in the tub. The vapor rose rapidly near the warm outer rim, flowed toward the center under the glass, descended at the cold center or pole, and out to the edge again at the bottom.

Upon revolving the tub the inflowing upper current ran ahead of the tub until the centrifugal force was sufficient to throw the vapor from the center and bank it up at a distance from the center, depending upon the velocity or speed of the tub.

The outflowing current at the bottom also turned to the right, thus making the vapor less dense at the outer rim than farther in toward the center.

The whole experiment illustrates beautifully the ideal circulation of the atmosphere upon a revolving globe that is hotter at the equator than at the poles. And further it shows that the arrangement of air pressure on the surface of the earth is due to its rotation.

THE MOUNT WEATHER RESEARCH OBSERVATORY.

By Prof. Frank H. Bigelow, *Washington, D. C.*

1. *The need of a modern research observatory for meteorology in the United States.*

The most obvious reason why the Government should build and equip a first-class observatory for research work in meteorology for the United States is that we may not fall behind other nations in providing for the advance of this branch of science. Other countries have such institutions on a larger or smaller scale, and we should have one of our own comparable in efficiency with the other lines along which the Weather Bureau has been developed during the past thirty years. It would take too much space to enumerate the various observatories in Europe and other parts of the world where, in addition to common meteorology, there are conducted a series of researches in terrestrial magnetism, atmospheric electricity, solar physics, explorations of the upper atmosphere by balloon and kite ascensions, spectrum analysis of the aurora and the lightning, investigations in the ionization of the atmosphere, the radio-activity of the atmosphere and the ground, and the other allied problems. What has been done by the Washington office in some of these lines has heretofore been of a temporary nature.

2. *The recent advances in physics which concern meteorological problems.*

A second and more weighty reason for expanding the traditional work of the Weather Bureau, which is better than the rivalry of different nations, consists in the hope of practical advantages in forecasting to be derived from the application of several results of the recent advances in cosmical physics. While these are rather technical and demand a high grade of scholarship for their development, there is a rapidly growing consensus of opinion among students of these subjects that a footing has been gained in the great field of solar-terrestrial meteorology which can not be neglected if we are to do our full duty to the American public.

The physical processes which are involved in the manifold effects of the solar radiation upon the earth have, as everyone knows, been studied for half a century by many scientists of serious purpose. There has always been found just enough agreement between the variations of several solar phenomena from year to year, sun spots, prominences, faculæ, coronas, and certain terrestrial phenomena, aurora, magnetic field, atmospheric electricity, barometric pressure, temperature, rainfall, and crop products, to make it entirely probable that an efficient synchronous connection exists between these two bodies of the solar system. But the scientific evidence has been more or less conflicting and debatable, and too lacking in persistency to satisfy those who are prone to criticism or who can only see conditions that require no insight or experience with details of observations and reductions.

Such a state of affairs is, however, inevitable in an attack upon this great citadel of nature; there is no battle without noise, smoke, cries of the combatants, wounded and dead men. Nearly every scientific investigation is merely a stepping-stone to a later research, and a multitude of individuals must fall by the way before the flag is planted on the rampart. It takes years, in so hard a problem as that of the sun and the earth, where the cyclic processes are slow, to collect a series of observations long enough to see how things are going. We have had astronomical observations of the positions of the sun, moon, planets, and stars for 150 years, but astrophysics is only 20 years old; observations of sun spots for 200 years, but of prominences only 30 years and faculæ hardly 10 years; magnetic declination 200 years, but of the complete magnetic elements only 60 years in one or two places, the other series being short; of atmospheric temperatures 300 years, but a good modern series of only 35 years in several parts of the world; of atmospheric electricity 60 years, but of the ionization and radioactivity of the air less than 10 years. Besides the shortness of our modern series of observations, it is found that these are not adequate to the duty imposed upon them by cosmical meteorology. They are not homogeneous, and the apparent residuals must in part be attributed to faulty methods in observation and reduction rather than to natural forces emanating from the sun. This mass of past material must be worked over and rendered uniform, and the future observations must be carefully organized to meet the demands of the case. The solar residuals in barometric pressure are inside one-tenth of an inch, and we must work down to the nearest hundredth, year in and year out; the temperature variations are limited to 2 or 3 degrees; no one knows what limit must be put upon aqueous vapor tension, upon the electric potential and the magnetic force, or upon the electrical conductivity and radioactivity of the atmosphere.

We have recently put our barometry on the right basis for the United States and are now working up the temperature and vapor tension. When similar reconstructions of material have been executed for the other portions of the earth we shall be in a position to declare how large our terrestrial residuals are and how many times the pulse felt in the earth's atmosphere should be multiplied to obtain the strength of the throb in the heart of the sun, whether 100,000 or 1,000,000 times. At present the watchword is organization and recomputation. The international meteorological committee has appointed a subcommittee for the combination and discussion of meteorological observations from the point of view of their relations with solar physics. This alliance between solar physics and terrestrial meteorology is to be represented by Angot, Langley, Lockyer, Pernter, Shaw, Angström, Birkeland, Bigelow, Cirera, Davis, Deslandres, Eliot, Hale, Hann, Janssen, Koppen, W. J. S. Lockyer, Ricco, Rizzo, Steen, Violle, Woeikoff. The American names, Langley, Hale, Bigelow, represent astrophysics on the side of radiation, spectroscopy, and meteorology with magnetism and electricity. This committee met at Cambridge, England, August 17–24, during the session of the British association, and they took steps to organize the entire subject both as to observations and as to their reduction and publication, seeking to cover the entire field and to secure reliable residuals of various kinds.

I may at this point briefly summarize what has actually been made out as to the influence of the sun as a variable body upon the earth's atmosphere and our climatic conditions. Beginning with 1830 we have a curve of annual variations which connects the sun spots, the terrestrial magnetic field and auroras in a so-called 11-year cycle, the large variations of one matching those of the other beyond dispute. Commencing with 1870 we have an annual variation curve of solar prominence frequency, which has a short 3-year cycle, and depends upon the circulations in the sun's mass, as shown in the periods of rotation, especially of the polar zones; this 3-year cycle is superposed upon the common 11-year cycle, and it is an important part of it. Besides breathing in a long period of 11 years the sun also has to take a short breath every three years, and a still longer one of 35 years. It is the three-year period—more exactly 2.75 years—that chiefly interests practical meteorologists, because that same solar convulsion is reproduced in our climatic conditions.

There is at present a dispute about the period of the rotation of the sun. All direct astronomical observations on the sun's surface give us a period of 26.68 days at the equator, falling off to 29.5 days near the poles, and there is no evidence whatever that the sun turns faster on its axis than 26.68 days in any part of its mass. On the other hand the terrestrial variations derived from auroras, magnetic field, thunderstorms, and barometric pressures, when computed by least squares, are said to give a period of about 26.0 days. No explanation has ever been made of this fact that we have a shorter period in the earth's atmosphere than the sun itself can possibly produce by simple rotation. I wish to call attention to the fact that the 2.75-year period seems to connect them, though I do not understand why it should do so; 2.75 years=1,004 days; hence by the formula—

$$\frac{1}{T}=\frac{1}{E}+\frac{1}{S}$$

and using the following periods:

	Days.
Assumed siderial period of solar rotation at the equator	24.87
The 2.75 year period	1,004.00
Period of the earth's motion in its orbit	365.25

and compounding the periods, we have—

$$\frac{1}{24.87}+\frac{1}{1,004.00}=\frac{1}{24.27}$$

for the accelerated siderial solar rotation period, and

$$\frac{1}{24.87}+\frac{1}{1,004.00}-\frac{1}{365.25}=\frac{1}{26.00}$$

for the accelerated synodic rotation period. This may be justified by the following:

$$\left.\begin{array}{l}\dfrac{1}{24.87}-\dfrac{1}{365.25}=\dfrac{1}{26.68}\\[2ex] \dfrac{1}{25.99}-\dfrac{1}{1,004.00}=\dfrac{1}{26.68}\end{array}\right\}\text{Synodic period.}$$

There is evidently some close connection between the observed periods—

24.87 (siderial),
1,004.00 ($2.75=\frac{11.1}{4}$ years),
365.25 (earth's orbital motion), and
25.99 (observed in terrestrial phenomena).

There may be some reason for this if there is a slow forward circulation in the solar mass besides its regular axial rotation. Moreover, in terrestrial meteorology we find this same short period of about 2¾ years in the barometric pressures and temperatures all over the earth, in the magnetic field, the electric potential, and probably in other elements, as the rainfall, number and violence of storms, and the crop productiveness. It is all a question of circulation in the mass of the sun and in the atmosphere of the earth. The influence is not direct and uniform from the sun to the earth's atmosphere as a whole. This air mass seems to surge back and forth, from year to year, between the eastern and western hemispheres, being at high pressure on one side and low on the other; the temperature is at the same time warmer in the Tropics but colder in the temperate zones. Even so the effect is more or less local, some places being sensitive and others sluggish. Thus Asia is sluggish, America, the Indian Ocean and South America sensitive, Europe and Africa rather indifferent.

In the United States this short period is distinctly reproduced in the pressure, temperature, number and intensity of our storms, and their position in latitude. The most sensitive region that I know of is the Rocky Mountain slope from the Dakotas to Texas, but the pulse is modified and confused by the rapid processes of the American cyclonic circulation. The range of these problems is enormous, and in the present stage of science complicated, but I have no doubt that the next generation will look upon our perplexities as unimportant.

3. *The equipment of the observatory at Mount Weather.*

In planning the details of a research observatory adapted to the future needs of American meteorology, it is important to keep in mind two or three leading ideas. There is a great amount of research in the subject of solar-terrestrial meteorology going on in various parts of the world, conducted by separate observatories dedicated to astronomy and astrophysics, to terrestrial magnetism and electricity, or to terrestial meteorology, and the total amount is likely to be very much increased in the future. This rich material is, however, of little practical use for forecasting weather conditions, for two reasons. The first is that the reports containing the results of the observations are not accessible to the world until two or three years after they have been made, except possibly in a detached and fragmentary way. On the other hand, the forecaster must have his data fresh and up to date to make any use of it in forecasting. The second is that these branches of science move on parallel lines and are mutually related, but in this age of intense specialization it is very seldom that scientists are trained to do justice to matters lying outside their own line of work. Thus, the astronomer is seldom a good magnetician and meteorologist; the magnetician fails in astrophysics and technical meteorology, while the practical meteorologist has deficiencies in solar physics and terrestrial magnetism. In fact, in order to make the most out of the information reaching the earth from the sun, it is necessary to lay hold simultaneously on all these more or less imperfect solar writings and attempt to make them supplement each other by a coordinated system of observations and discussions. To accomplish this purpose for the American public there seems to be no better way than for the Weather Bureau, which is officially charged with the investigation of atmospheric phenomena, to found a research observatory of sufficient power to cope with the entire problem and to provide for all the developments likely to arise in the future. As you know, this policy has been adopted by the Secretary of Agriculture, and during the past two years the Chief of the Weather Bureau has made progress in that direction. We have a fine site on the Blue Ridge Mountains, at Mount Weather, 5 miles south of Bluemont, Va., comprising 90 acres, overlooking the Piedmont Plain on the east and the Shenandoah Valley on the west. There are in process of construction now, or soon to be begun, the following six buildings:

(1) The administration and meteorological observatory proper, for the usual meteorological observations of pressure, temperature, vapor tension, wind and cloud motions, and such other data as may be needed to supplement special researches in other branches. This building is already completed.

(2) A balloon and kite establishment for the manufacture of all the needed apparatus, hydrogen gas, and all that is required in ascensions. There are in America no great manufacturing plants of balloons such as exist in Germany, and we shall have to depend upon our own people to provide our equipment. This work will contribute to our studies of the structure of cyclones and anticyclones especially by furnishing temperature readings in the higher strata and in all the subareas surrounding the centers of high and low pressure. We expect to make kite ascensions daily to 2 miles, and balloon ascensions to 4 or 5 miles as often as possible. There is good reason to think that with self-exploding balloons we can often reach 10 miles elevation at the Mount Weather site, since such balloons can make this ascent and fall in about one hour. This building is in process of construction.

(3, 4) The magnetic observatory will contain a constant temperature room, built on the best known plans, for self-registering the magnetic variations, and a control temperature room for absolute measures and special experiments. The rocks on Mount Weather are as nearly nonmagnetic as the best marbles, and the magnetic field is very uniform over the observatory site. This enables us to build of our own rocks, except where fitted surfaces are required, as in the piers. It has been proved conclusively that there are large terms in the magnetic field which are strictly meteorological in the sense that the solar radiation produces the magnetic effect, just as much as it does the diurnal and annual variations in the pressures and temperatures, wind currents, rainfall, and electric potential.

The United States Coast and Geodetic Survey is charged by law to make the geodetic surveys and investigations in the secular variations for the United States, while the terms depending upon solar and terrestrial atmospheric conditions fall to the Weather Bureau by the laws of Congress, under the general head of meteorology. These two buildings are in process of erection and will be equipped during the coming year.

(5) The physical laboratory is designed to contain office rooms for the magnetic observatory, the solar physics observatory, and for physical researches in atmospheric electricity, ionization of the air, radioactivity of the air, soils, and spring sediments, specimens of which will be collected from various parts of the United States. This laboratory is designed to carry on special researches in physics, such as meteorology demands with ever-increasing insistence. It will have a constant temperature subbasement, a basement with dark rooms, sets of piers with long and short bases for experiments in light, heat, and electricity; a floor for chemistry, glass blowing, photography, and general physics; and a third floor for library, study, and computing rooms.

(6) The solar physics observatory will combine by means of a composite horizontal telescope the necessary apparatus for observations on the solar surface and for the examination of all types of radiation phenomena by the spectrum and by heat absorption. It will consist of a large coelostat with two 20–25 inch mirrors to give a horizontal beam of light directed from south to north. The objective plane will be fitted with a 40-foot lens for photographs and spectroheliographic studies of the spots, faculæ, and the photosphere generally; with a large direct prism for studies on the solar spectrum; and finally with a stop grating to supply a beam of light to a Langley bolometer. This will be supplemented by actinometers and such pieces of small apparatus as may be found necessary. It will, of course, take some time to equip and organize such an observatory as that described. The chief difficulty will be to secure the services of scientists sufficiently expert to carry on valuable researches in these advanced subjects: Buildings and instruments can be paid for with money, but successful research scientists must be discovered by natural selection. It is intended to make this observatory the training school for such assistants as seem to possess a scholarly inclination and the force of character required for such work, and we may hope that the future will discover some successful investigators among our Bureau people.

4. *The problems and observations which can be undertaken.*

It is difficult to assign in advance a complete programme of observations for Mount Weather, since the field is complex and extensive, and much will depend upon the men and money placed at our disposal by the Government. The advance of science in cosmical meteorology is rapid, comprising new subjects of research and a continual development of new apparatus, so that we must to some extent adopt an expectant attitude and plan the buildings to accommodate all kinds of probable improvements. We can, however, lay down some general principles for our guidance. The first is the establishment of a standard series of fundamental observations in the primary lines, namely, in atmospheric pressure, temperature, and vapor tension; in atmospheric electric potential, ionization, and radio-activity; in atmospheric magnetism in the several periods; in radiation from the sun and its variation diurnally, seasonally, and annually; and in the visual appearance of the sun as displayed in the frequency of the spots, faculæ, prominences, and the photosphere generally.

The main problem is to determine the output of the solar energy in its various forms and the effect upon the circulation of the sun's atmosphere and synchronously upon that of the earth. Unfortunately, it is not possible at a given station to measure these quantities regularly every day on account of the common cloudiness. There will be gaps in the record from time to time. We have, however, one element that is not affected by clouds and one which goes on steadily day in and day out, which can be measured, namely, the changes in the magnetic field. This is a sensitive measure of the whole solar-terrestrial system; it takes in and sums up the entire cosmical pulsation. In fact, it is too sensitive for our present knowledge, because we have not yet learned to interpret it fully.

The time will come when we shall understand what all the minor fluctuations on the magnetic traces do stand for, just as we now know fairly well what the minor turns on the barometric curves signify. If we consider this magnetic pulse to register continuously the solar action upon the atmosphere, with the other instruments we shall on clear days get such observations as will enable us to interpret the magnetic field at certain intervals. We can, as it were, standardize the magnetic force at occasional points and then make our interpretations for the entire series. Thus the absolute magnetic measures will be made once or twice weekly, the atmospheric electricity and ionization will be measured daily; the solar radiation can be recorded only on a few clear days, possibly three or four times each month; the spots and prominences can be counted as often as the sun is visible for an hour or two during any part of the day; and the more special researches on the solar surface for the studies on the constitution of the sun can be made as circumstances suggest.

In every way possible it will be required to turn all our resources of information upon the solar field until we learn to pick out the best and most effective pulse, the one which is adapted to American meteorology. The magnetic observatory and the solar physics observatory lend themselves to these purposes. The physical laboratory will be used to adjust our instruments and invent new ones, to test and discover the best physical processes in the application to the atmosphere, and to afford rooms for the library and for the computers. It will be a great advantage to remove all the disturbances incident upon study and discussion from the two observatories, in order that the instruments may be kept quiet and undisturbed when moving about while engaged in other kinds of work. The balloon and kite plant is evidently of practical importance in gaining information regarding the physical effects of the temperature and pressure in the upper strata, and as I shall have more to say on this subject in my other paper, we need not now pause longer on this topic.

Besides these regular observations there will be special investigations in many directions which will arise in developing cosmical meteorology in so extensive a field as that involved in its application to the United States. These will naturally suggest themselves by future experience.

5. *The relation of the data to processes in forecasting the action of cyclones and anticyclones, and the problem of long-range forecasts of the seasons by means of the synchronism between solar and terrestrial actions.*

One properly inquires what prospect there is of actually improving our forecasts by means of this new line of work. In answering this much or little may be said, as one is disposed to look at the subject, but I shall at least express my own opinion with entire frankness, basing my judgment upon many years of work along these lines of study. We have been seriously handicapped in bringing these results to a final practical basis by two or three causes which can be remedied in the future. There has been a lack of students interested in the cosmical problem who are really capable of adding usefully to its solution. Highly trained men in mathematics, solar physics, magnetism, electricity, meteorology, and physics are indispensable.

Experts in these several lines must be brought together to work in harmony to the common end. On the other hand, the available observations are really very imperfect. They are often fragmentary, consist of short series, are not homogeneous, and have been taken at different places and under widely varying conditions, so that they are only roughly comparable. It is in our power to improve these circumstances in the future. On the other hand, there is great encouragement in the tremendous impetus that is now being acquired by the scientific world in this direction, constituting a veritable revolution within fifteen years. Many of the ablest men in the world are devoting their energies to various parts of the general problem; special observatories are springing up in all portions of the world, equipped with expensive and magnificent pieces of apparatus; and the literature on the subject is growing enormously, so that it is becoming impossible to keep up with the various branches of it. From all this intellectual energy the world is sure to derive practical benefits. There is genuine encouragement for such labors, or else so many learned men would not be devoting their lives to these studies.

Let me trace out the probable course of the solution of the forecast problem in a few concluding words. The various steps are only partially complete, but enough has been done to draw the outline of the result. The sun is an enormous body, nearly a million miles in diameter, which is working by its own laws from a higher to a less active state—from a higher to a lower efficiency. Meanwhile it is circulating within itself, by convection, which produces a variable system of currents within its mass. The effect of this is shown by periods of rotation, which are longer at the poles than at the equator. These periods fluctuate back and forth, slower and faster, from year to year, about a mean rotation period, and we find a conspicuous 11-year period, together with a minor 3-year period. These cyclic operations are also shown in the number of the spots, in the frequency of the prominences and faculæ, and in several other changes of the solar surface. These are the superficial signs of what is going on in the mass, just as a fever flush on the skin is a symptom of the state of the internal circulation. These movements in the sun are leisurely, as we count time on the earth, and they are of large amplitudes when we consider the enormous forces that these surface signs stand for in the solar laboratory. We now possess the 3-year curve for thirty years and the 11-year curve for a couple of hundred years.

Besides these visible effects on the surface of the sun, there are yet more powerful invisible products in the radiation energy that is being poured out in every direction. There is the common electromagnetic wave radiation, the electric-charge radiation, and the magnetic field, all of which act like a wireless telegraphy on a tremendous scale between the sun and the earth. We only need some more suitable receivers at the earth, and time to study out the solar code, which is at present an unknown language to which we hardly can be said to hold the key. We may have discovered a few letters in the solar alphabet, but the grammar and dictionary have yet to be constructed. At the earth, corresponding with all this solar variation of energy, we have made out certain synchronous movements in our own atmosphere. The earth's atmospheric circulation depends absolutely upon the solar energy received by it, and hence the seasonal and annual changes in the climate of any country must ultimately respond to the primary impulse of the sun. We have, in fact, found that the three-year solar cycle does reappear in the atmospheric pressures and temperatures of the earth, in its magnetic and electric fields, and generally in the climate and crop effects. The sun acts through the medium of the earth's atmospheric circulation, but unfortunately it here greatly complicates our problem, for the pressure, as stated above, surges from one hemisphere to the other, or else from the lands to the ocean, while the temperature inverts between the Tropics and the middle zones.

In all this turmoil of circulation some regions respond badly to the solar impulse and some are sensitive to it. Thus, Europe and Asia are not so good receivers as is North America, and Africa and Australia fall behind South America in receptivity. To work out all the details of this meteorological action will of course require many years. The United States fortunately has a very good pulse in the solar-terrestrial circulation. We have many cyclones developing on our territory, the eastward drift is rapid, and the high-pressure belt crosses our Southern and Pacific States, so that our location is excellent.

We have found the 3-year cycle in the number of our storms and cold waves, also in their position on the continent, and we have only to work up the data fully in order to trace out the general law of sequence, so that we can forecast a year ahead. There is good reason to hope that future meteorologists will give us very approximate forecasts of the kind of seasons we are to have in the United States. Furthermore, besides the 3-year cycle which shows itself in the seasonal conditions, we have variable amplitudes in all these curves to study. The amplitude is the swing in a curve every few days, as from warm to cold or from low to high pressure in the cyclones and anticyclones passing over a given State. The curves swing wide and wildly some years, but they settle down and are calmer in other years. This comes out most clearly in the 11-year cycle for the magnetic field, the barometric pressure, the temperature, and the wind velocity. This is a pulse of great power, and the subject ought to be carefully worked up.

It will be seen that so many lines of research develop as to become bewildering to an outsider, and it certainly requires many workers to keep the current data all computed up to date. My own difficulty in the research at Washington has been that with so much to investigate by way of trial, in order to find out the best line of work, it is impossible to keep in operation all the veins that have been opened. The new observatory force must needs be a large one if we are to cope with the great problem before us. It will require a few able men to direct the several lines and coordinate them, and many others to make the necessary computations. Every instrument in use requires careful study, adjustment, and correction, and every observation must be suitably reduced and discussed.

It will require several years to develop a proper observatory routine before the homogeneous series will bear fruit in practical forecasts. But in view of the immense benefit to civilization—to the health and comfort of the people of the United States—to be derived from a more correct knowledge of the probable weather conditions, what are a few years of experience and a few thousand dollars of the public money?

DISCUSSION.

The **Chair**. I shall be especially glad to hear all opinions on this subject. It is one of the most important problems we have to consider to-day.

Professor **Marvin**. There is one problem we might take up at Mount Weather, among others. It is in regard to our anemometer. I shall make some remarks later as to what we know about the measurements of the velocity of the wind. It seems to me the power plant at Mount Weather will be peculiarly useful for the study and testing of the anemometer. At velocities above 50 miles an hour we know very little about the velocity of the wind. The indications of the anemometer can not be accepted as to the real movement of the wind. Now, I propose as one problem there the standardizing of the anemometer, and I think we ought to approach the problem from more than one point. We must use more than one method of standardizing these instruments. Heretofore the principal forms of testing apparatus have been made by constructing a vertical axis with a long horizontal arm on it. I will not attempt to describe all the accessories, but this apparatus is properly supported so it can be revolved about a vertical axis, and the anemometer travels through the air at different velocities according as the arm is rotated.

We ought to make experiments at Mount Weather with very high velocities. I propose that we construct in our balloon house a long tunnel of this general character. [Drawing on blackboard.] Here is a closed tunnel with a partition separating it into two parts. In this portion of it we shall put a powerful fan which will revolve at different velocities by means of a powerful engine driving the air about in that tunnel at all sorts of velocities. We ought to go as high as 120 to 150 miles an hour. We have records at such a station as Point Reyes light indicating velocities of 120 miles an hour.

What the real velocity is we know very little about. This is merely a suggestion. I can not attempt to indicate, in detail, the lines along which such a study should be carried out, but I hope we can take up such problems as this.

This is a practical problem that bears on the daily work of the Bureau. It will not necessarily have to be continued for many years, but it is a problem I think ought to be taken up.

Professor **Abbe**. We must recognize that the atmosphere under the influence of the sun is really a great hot-air engine, and all the energy that it receives from the sun must be accounted for. At first the sunshine evaporates the water, heats the ground, and heats the air. Then the warm air and the moisture introduce differences of density, whence follow the motions of the air or the winds. Gradually the heat is lost by radiation into space, and the atmosphere would settle back to its initial quiet condition were it not for the periodic diurnal and annual influx of new supplies of heat. The distribution of continents and oceans, clouds and snow, introduces a great many sources of disturbance, so that the movements of the atmosphere recur with great irregularity. As three-fourths of the earth is covered with water, we may consider the continents as introducing disturbances into what would otherwise be a comparatively simple problem. These disturbances are propagated daily and annually around the globe from their origin over any continent, and they affect distant regions appreciably. They introduce cycles or periodical disturbances, and as we have six continental masses to deal with the combinations of these cycles become very complex. Both observers and mathematicians must cooperate in unraveling this complexity. Possibly experimental laboratory methods may be devised to assist us. While one studies the sun itself and the nature of its radiations another must study the surface of the earth and the irregularities produced by it. If both fields of labor are carried on together at Mount Weather we may hope for the happiest results. But we must remember that research is a very serious matter, and nothing but failure can be expected if we go into the work without a proper preliminary training. We shall deem ourselves fortunate if out of several hundred Weather Bureau men we find two or three who show themselves capable of extending the boundaries of our knowledge about the movements of the atmosphere. We shall be still more fortunate if without waiting to instruct and train ourselves in research we succeed in attracting to our corps a few of the men outside whose genius for research has already been recognized in their published works.

Mr. **Cuthbertson**. I have experienced a great deal of pleasure in reading, in the report of the Chief of Weather Bureau for 1903, of the proposed establishment of the Mount Weather Research Observatory, as well as in noticing the progress made along certain lines of investigation which it is intended to carry on more fully at the proposed observatory. More particularly, however, was I pleased with the results already obtained at the very beginning, which promise a material improvement in the accuracy of forecasts by pointing out more definitely the probable course and the rapidity of motion of cyclones and by foreshadowing the rain areas more clearly and for a longer period than by the usual method. The equipment and the methods of procedure are admirably planned, it seems to me, and certainly placed in the best of hands. The wide range of investigation pursued by those in charge of this work, and, furthermore, their intimate acquaintance with all the details connected therewith, make them the best judges of the course to be pursued at the beginning and the variations to be adopted during the progress of the work. I presume it will be necessary at times to call on certain appropriately located stations to carry on particular series of observations that can be performed at these stations, and I am certain that the officials at such stations will, as heretofore, feel a special pride in the opportunity to assist the observatory in its mission. The only suggestion I could make (and in this I have probably been anticipated) is that during the progress of the research work reports of results that are applicable to the work at stations be sent out from time to time and in such form as to enable station officials to master them and apply them intelligently, thus keeping this class of workers in the best possible state of usefulness and able to put into operation rationally any and all improvements that have been found to be advantageous. The preparation of isobaric charts of the 3,500-foot level and the 10,000-foot level at stations has been suggested. There are stations—Buffalo, for one—at which the preparation of maps and forecasts for the mails, the press, and the chambers of commerce often tax the station force nearly to the limit; but if the preparation of these additional isobaric charts will improve the accuracy of forecasts, as promised, I think it should be done by all means, as it would undoubtedly be well worth the employment of an additional assistant, should this latter be necessary. The published matter in reference to the observatory and its proposed work shows that the plans have been worked out so thoroughly by Prof. Willis L. Moore, Chief of Bureau, and Professor Bigelow and his coworkers, that a station official finds it difficult to make any suggestion for which provision has not already been made.

Mr. Tarr. It seems to me the establishment of this laboratory at Mount Weather is the most important advance that has been made by the Weather Bureau. It is practically the beginning of a new era. Heretofore we have been studying the weather indications at the surface of the earth, but now we are to begin to study them at the higher altitudes, and with the research work that will be done there it seems to me that the problems that have been so difficult for us to solve will be made quite easy with the methods, the apparatus, and the men that will be there. Those of us who have taught meteorology have probably realized the fact that while there is an abundance of theories regarding the various phenomena we study, there are very few absolute laws laid down that we can teach to others. In this research work theories will be developed into laws, so that when we come before a class instead of stating certain theories which have been held and advocated we can state absolute laws.

Professor Moore. At Mount Weather we shall make and send out the apparatus for the exploring of the atmosphere to altitudes of from 3 to 10 miles. It is probable that many balloons will be simultaneously liberated from different stations, so as to get records of storms and of cold waves from their four quadrants. With the knowledge thus gained of vertical gradients of pressure and of temperature we may gain a better understanding of the mechanics of storms. This exploration will be useful in determining how near right are those who believe that change in temperature other than seasonal is mainly a function of the mechanics of the lower atmosphere—that portion lying below the 10-mile level—and that in the study of those aberrations of climate called " weather " we need concern ourselves only with the atmosphere near the earth, and that variations in the condition and in the intensity of the many forms of solar radiation are inappreciable in their effect on the weather of the earth.

With observations from the magnetic, the electric, and the solar-physics observatories that we are now building and that will be equipped with the most approved appliances opportunity will be given to those who believe that the cyclonic or anticyclonic whirls that constitute storms or cold waves are mainly the result of changes in the amount or intensity of some form of solar radiation. It is my opinion that the synchronism of changes in the activity of the chromosphere of the sun and the weather of the earth has not yet been established with sufficient definiteness to be of benefit to the forecaster, but a working hypothesis has been formulated which stimulates thought, study, and investigation. This fact must be credited to the patient work of Prof. Frank H. Bigelow. Even those who differ from him in their conclusions relative to the association between astrophysics and meteorology must admit that the fertility of his thought and his earnest seeking after the problems which, when solved, shall raise meteorology from empiricism to a closer approach to an exact science, have been highly beneficial.

The study of storms has too long been made from a single viewpoint. We need daring minds, even those that are willing to take a considerable hazard in the hypotheses which they are willing to lay down and attempt to demonstrate; for to doubt is to investigate. New truths are usually discovered by working inductively along conventional lines, but some of the greatest principles in nature have been made known to the world by deductive reasoning and by the assumption of an hypothesis that could not at the time be demonstrated. We must be tolerant of each other's opinions and strive earnestly for the elucidation of the many difficult problems that now confront the meteorologist.

We purpose to make the research at Mount Weather catholic in its broadness. We shall look for the truth and shall not despise its source or the means of its conveyance. We shall discuss meteorological observations from the point of view of their relations to solar physics. We shall select meteorologic and magnetic elements and compare them with solar observations; we shall carry on research in the allied subjects of radiation, atmospheric electricity, ionization of gases, radioactivity, etc.

Progress in our knowledge of the effects of the sun's actions upon weather conditions depends upon introducing more refined processes than have generally been assigned to meteorology. We wish to determine the nature of the alliance between meteorology and solar physics. The atmosphere of the sun and of the earth, together with the connecting radiations, will be studied as one branch of science having common interests, which may be designated as cosmical meteorology.

In our seven buildings at Mount Weather we will have the most approved apparatus for measuring atmospheric electricity and magnetism, for measuring the solar radiation in the spectrum, for registering the sun-spot areas, the prominence output, and the extent of the faculæ. They are all valuable as registers of the solar energy, which, falling upon the earth, may play a part in stirring up the atmosphere and producing our weather.

The climate and crop conditions from year to year depend largely upon the invisible and subtle solar radiations, known to exist as waves, like those used in wireless telegraphy. The space between the sun and the earth—that is, the cosmical ether—is filled with wireless messages which we are laboriously learning to interpret. We do not understand the solar code very well, and the process of deciphering it is like that of learning to read the Babylonian inscriptions; namely, by putting this end and that together, learning to read a bit here and there, by intercomparisons, trial and failure, till at length the language of the sun shall be understood. The time may come when we shall be able to interpret the seasonal weather from year to year in advance. It is not now. The sun moves leisurely through its cycles, and the terrestrial conditions seem to follow loosely. At present what information we have concerning these matters comes in scattered form from observatories, in reports two or three years old. We must therefore have our own instruments, our own trained research observers and computers, and a discussion of results.

During the past year the main building of the Weather Bureau observatory has been completed, the power plant and the building from which balloon ascensions and kite flights are to be made have been erected, and the magnetic buildings started. It has been found that the rocks are entirely free from magnetism and that the field is uniform, so that it is a suitable place on which to locate a magnetic observatory. A physical laboratory for electrical and radioactive effects is being planned, the erection of which will take place another year. Finally, a comprehensive physical observatory for photographing the sun directly and through the spectrum, for measuring the radiation energy by actinometry and bolometry, with their allied equipment, will be required. This complex institution must grow up slowly, as plans can be matured along the best modern lines. Our assistants must be trained to work in several lines on a harmonious general plan, and the results must be carefully studied as the science progresses.

J. Warren Smith. In selecting men to carry on the special work at the Mount Weather Observatory, I will respectfully urge that men already in the Weather Bureau be considered.

The easiest method will be to hire physicists already trained in solar physics observations and the care and handling of the necessary apparatus. But it seems to me that we have men in the Bureau who have a basic education sufficient and who have shown enough fitness for scientific investigation to warrant training them for study and investigation in higher meteorology.

The possibility of being selected for that work would serve as an incentive to many men in the Bureau.

As to the utilization of the observatory facilities by the station officials themselves, I would suggest special lectures and instruction at Mount Weather.

As an instructor in meteorology I feel the need of direction in the handling of the special instruments and in the discussion of the more complex problems of the science of the atmosphere.

Most of us have taken up the work of teaching as we thought best, and with the text-books that we found most available; while I believe that our system and method of teaching should be unified and placed under the direction of some man connected with the observatory. Then we should be given a course of lectures upon the mechanics of the atmosphere especially and upon the science of meteorology as a whole.

Further, officials of the Bureau who have opportunity and inclination to make special investigations should receive some instruction as to what has been accomplished and the particular lines that seem especially promising. We would not then duplicate effort, but could take advantage of the work that has been done, and our whole investigation would be taken up intelligently and systematically.

Doctor Fassig. It is certainly very gratifying to realize the high aim placed before us in the establishment of the Mount Weather Observatory, and the broad foundations that are being laid for future work, for it is all in the future. One point in this connection that I would like to bring out is the importance of making Mount Weather or some other center the headquarters for all the research energies that are being expended in the service by men on station as well as by men at Washington or at Mount Weather. It seems to me, in looking over the service, that there are a great many men on station, away from the influence of the Central Office very largely, who are capable of carrying on local studies, or studies of wider character and application, but who need some direction and some assistance from a place like Mount Weather.

Professor Bigelow. You have heard one side of this matter, and a very important one, and you will not take it amiss if I call your attention to the other side. It is very easy for us to build castles in the air—very easy, and even desirable, to work up this enthusiasm—but enthusiasm is not counting the cost nor the risk of disaster. I do not refer to the cost in money that has gone into buildings and instruments. Nearly anybody can put together an observatory if they know what they are about and take the trouble to consult other people, but when it comes to research work as distinguished from routine work you are in a very different category. To do the sort of work that one can teach another and can be reduced to routine—such work as goes on in the average astronomical observatory like that of Harvard University, the Naval Observatory, etc.—that is an easy thing, but research work is a wholly different thing. Any man who has done research work knows that I speak the truth. You can not always hire a man with money; you can not necessarily educate him and be sure you have your man. He may know a lot of things—physics, mathematics, all sorts of things—but research work is new work that has never been done before. You are on new ground, and no one can tell you what to do. It takes faith, it takes power, it takes character, such as you do not dream of if you do not possess them. It takes power like that of J. J. Thompson, in England. A splendid man, a born genius, an able mathematician, a fine scholar, he grew up step by step, building brick by brick, until he became the leader he is. It can not be done instantly; it takes power plus education. It is a serious thing, gentlemen, that we are undertaking. I do not say this to discourage you, but to tell you what I know is the truth. To undertake research work lightly, because you are enthusiastic; to take lightly into your hands the reputation of this Bureau of the Government and the responsibility to the people that lies upon us—do not do it. If you have not the power of research and can not bear years of discouragement, you should not touch it.

So a great responsibility rests upon our Chief and the Secretary. I believe there is an immense future for us, but we must know how to go about it. We must not only erect buildings and put in instruments—we must build our men. I do not care where we get them. If anyone here has true research ability, so much the better; if not, let us be cautious. If we have to go outside, even to Europe, for the first great man, by all means let us do so.

Professor Moore. Professor Bigelow has given expression to the thoughts that have been running through my mind ever since we began with Mount Weather. It is easy enough to buy instruments and erect buildings. The difficult problem comes just now, as Professor Bigelow has described it. It is the hardest problem we have yet met in the Weather Service. But we are not going to meet it by being afraid of it. We are not running away from it.

Where did J. J. Thompson come from? Did the institution now honored by him and his work get him already created? No. It took some young, aspiring fellow and made J. J. Thompson out of him. We could not get him if we wanted him. His future is made. We must first build our institution. We must next look for the men who may develop themselves with our aid, and somewhere in this service—I hope somewhere in the seats before me—may be developed a J. J. Thompson. I do not see where we can go to get the men to do the experimental work that we want done—the physicists, the mathematicians, the astronomers, who appreciate our particular problems. It seems to me we shall first have to take our own well-developed men, who have had good preliminary education, and when we see a man who, we think, has the talent to add to this science of ours, we will send him wherever it is necessary to send him to give him additional advantages. We may have to wait two or three or four years before we begin some of our lines of research. I am looking right now for men who have the capacity to grow—who will build themselves up when we give them the opportunity—but it is the most difficult problem in the whole of this Mount Weather research.

There are many lines of research that Professor Bigelow will admit he is not competent to carry on at that institution. He knows the general principles, but the details of the working out must be by some men with capacities other than those he possesses, or the capacities possessed by Professor Abbe, or Professor Marvin, or still others of our scientific men.

So, with the help of our scientific staff, I hope first to create an opportunity, and we shall have to wait for the man to embrace that opportunity, but we certainly will never get him unless we do create it. As I said, it may be necessary to take some of our own men and send them for training under Trowbridge, Thompson, Barus, and others, in the work of the laboratory especially, for the investigations we want carried on. Assuredly, if you could bring to us a perfectly developed man of high talent, who could organize and direct certain lines of research we want carried on, we should feel like taking him. And still a certain pride in our own institution compels me to say I would sooner wait a little to see if we can not produce something ourselves.

One word more: I am in thorough sympathy with Professor Bigelow. He has given expression to my whole thought; but I do not think he is discouraged. He has simply showed you some things we have to consider. But in regard to such men as Ferrel, Mendenhall, Barus—all able men; especially is Barus a great man—there is one mistake Professor Bigelow has made. None of these men left the Weather Bureau as it is now constituted. Would any of these men leave this meteorological service if they were here to-day and had this opportunity offered to them? [Applause.]

Professor GARRIOTT. It appears proper and, in fact, imperative, that the most liberally endowed and best-equipped meteorological service in the world should take a lead in research work that will be necessary to a further advance in meteorological science.

The Chief of the Weather Bureau has assumed a lead in this direction in the establishment of a station on Mount Weather, Va., that will be equipped for securing not only records of the weather but also records of magnetic and solar variations that are supposed to be associated with and have a controlling influence upon the various phenomena of the atmosphere that contribute to produce terrestrial weather.

It is apparent, however, that meteorological-research work that is calculated to produce positive results must be conducted on a world-wide basis, and that meteorology must assume a more intimate relation with astronomy, or, at least, depend upon solar observations made at astronomical observatories for much of the comparative data that will be required in meteorological calculations.

The widespread interest that is now indicated by astronomers in solar-investigation work, and the expressed opinion of leading scientists that the future development of meteorology lies in the association of meteorological observations with records of solar variation and terrestrial magnetism appear to indicate that the time is not far distant when the character and number of meteorological, solar, and magnetic observations will lead to a solution of some of the present obscure problems of weather and seasonal abnormalities.

The apparent effect of solar variations in the solar output upon the greater atmospheric bodies is referred to in my paper on "Long range weather forecasts," and it is known that the character, position, and movements of the greater areas control periods of normal and abnormal weather.

As it applies to weather forecasts, the research problem is found in the great continental and oceanic areas of high and low barometric pressure, and its solution depends, in part, upon a consideration and study of these areas in connection with the actual work of weather forecasting. The success of future efforts to advance the periods and accuracy of forecasts will depend more largely, however, upon a determination of the extraterrestrial influences that occasion abnormal distribution of the earth's atmosphere, and it is believed that these causes will be revealed by magnetic and solar observations that will be taken at Mount Weather and at well-distributed astronomical and meteorological observatories throughout the world.

Mr. CHAFFEE. In this new work we are not looking for men—the Chief of the Bureau is not looking for men—to study up old lines of research. We are looking for scientists, or men who may not be scientists now, with the courage to reach out into the unknown fields of science; men who do not fear to be scoffed at as visionaries, and at the same time men who have grown up with heart service, as our men have grown, in demonstrating and developing our work as a public bureau. Unfortunately for the old men in the Bureau, or for the Bureau in its early days, the pay and emoluments of office were not sufficient to attract the men of best education. But the Bureau now is getting in young men of more advanced education than was possessed by the early members of the Bureau, and they are imbued with that heart service, which I believe is being taken from the old members of the Bureau, that will do much to aid in the development of this new work at Mount Weather.

Mr. **Loveland**. I remember the words of a prominent educator, who said in substance that rapid advance in any science had not been made by the great men, but that close application, hard work, and the development of science had made those men great.

Mr. **Jennings**. Some of our older members will recall that we had an observatory at Fort Whipple, which was the school of instruction, and we all got into ruts at that school. It has been one of our hardest tasks to get out of those ruts. We need just such an institution as it is proposed to put upon Mount Weather to get meteorology out of the old ruts that we got into thirty years ago.

Professor **Abbe**. Something has been said about getting the proper sort of men for Mount Weather. We should take the best we can from our own men. I think it is intended to have a course of education and instruction. I have been laying out quite a course for the use of college professors who are teaching young men physics and who tell me they really want to give attention to meteorology. So I have been getting up quite a system of suggestions as to what they can do in turning young men toward meteorology. I think my paper to-morrow may help out.

Professor **Moore**. Professor Marvin has a paper on the errors in instruments. Before he goes on with it I want to say in regard to the problem he gave on the blackboard that I can assure him, when we get established at Mount Weather, he will have all the opportunity he wants. There are 90 acres there, and he can spread over 85 of them if he cares to. Five acres will do for the rest of us. I would like very much to have Professor Marvin take up this problem of improving the anemometer and our methods of measuring the velocity of the wind. We know it is very imperfect. I am sure Professor Marvin is able to solve that problem and devise an instrument that will give accurate measurements of the velocity of the wind. It would be one of the things that would redound to the credit of this Bureau and show the use of that observatory.

ERRORS OF METEOROLOGICAL INSTRUMENTS AND LINES ALONG WHICH IMPROVEMENT SHOULD BE SOUGHT.

By Prof. C. F. **Marvin**, *Washington, D. C.*

A clear understanding of the nature and magnitude of the errors and defects that affect meteorological observations and apparatus is a first and essential step in entering upon any serious study or discussion of data or the invention and development of new and improved forms of instruments. The subject is a very broad and extensive one and only a few features can be discussed in the present paper.

We must recognize at least three distinct classes of errors, namely: (1) Errors of exposure; (2) the accidental and unavoidable errors made by the observer, and, finally, (3) the errors inherently connected with the instrument, whereby it fails to measure or indicate correctly the physical magnitude or phenomenon intended. In addition to these three classes of errors, properly so called, we should recognize also the special and characteristic defects of this and that mechanism, which at times cause the complete failure of the instrument and the loss of record, particularly in the case of automatic apparatus. Recording instruments, moreover, of almost every kind require to be "set" to the indications of some nonrecording standard, and, in general, it thus results that all the errors affecting a reading of the standard are superadded to those of the recorder. Again, one function of every recorder is to measure "time," hence "clock errors" constitute a distinct and independent group of inaccuracies in this class of apparatus. These several classes of errors, defects, etc., must be clearly differentiated and considered in any careful discussion of our subject, but, with a few exceptions, I shall consider at this time only certain important cases under class 3, namely, the errors inherently connected with the instruments themselves.

Barometers.—Taking up the instruments separately, it may fairly be said we believe that mercurial barometers of the kind furnished Weather Bureau stations are probably the most precise of any of the instruments employed. The static pressure of the air is the physical magnitude sought to be measured. The structural nature of the instrument is such, however, that variations in temperature and changes in the force of gravity also produce changes in its readings. Fortunately, however, errors due to these causes, together with others due to capillarity and faulty mechanical construction, imperfect vacuum, etc., can be very satisfactorily eliminated by means of appropriate corrections. Under favorable conditions, as, for example, at the central office, the absolute value of the air pressure can be determined from a single reading to within plus or minus three or four thousandths of an inch—that is, one part in about ten thousand. Instruments that have been shipped to station are likely to suffer deterioration in transit, with a corresponding loss in precision. Notwithstanding this, in ordinary barometric work we attain in general a precision of something like one part in from one to five thousand. This seemingly high degree of accuracy is greatly cut down, however, when we consider not the absolute pressures but the changes of pressure from hour to hour or day to day. These changes are relatively small, but at the same time are of great importance, so that extreme accuracy is still the more necessary, especially in all those cases in which the diurnal and other periodic fluctuations of barometric pressure are the subject of study. The hourly readings, as deduced from barograph curves, are most frequently employed in studies of this kind. Now, most of the ordinary barographs are slightly sensitive to changes of temperature, and where special precautions are not taken to the contrary the instrument is subjected to a very considerable diurnal temperature change. This undoubtedly produces in various cases an appreciable periodic swing that is superposed upon *the true* barometric change, and finally, by the ordinary processes of harmonic analyses, is brought out as a barometric wave of small amplitude, whereas, in fact, it may be nothing but an uncorrected influence of temperature. Barometric observations are also affected by certain other slight errors that result from the action of the wind, which compresses or rarifies the air within the office, or even within the cistern of the barometer itself if the latter is freely exposed. This effect is quite perceptible on windy days.

Notwithstanding these limitations, however, barometric observations such as made by the Weather Bureau meet practically all the present needs of meteorology and leave little to be desired in point of accuracy. I believe they are unsurpassed in excellence by similar observations made anywhere else.

Thermometers and hygrometers.—Mercurial thermometers, in point of mechanical design and construction, are likewise capable of yielding results of very great precision. As employed in meteorology for the measure of the temperature of the free air and its moisture contents by the aid of the psychrometer, those errors that are strictly instrumental are of secondary consequence compared to errors of exposure and observation; that is to say, the strictly instrumental errors can often be made so small as to be negligible compared to the larger, unavoidable errors due to faulty exposure or made by the observer in reading the instrument. This result is not always attained in actual practice, but on the strength of this argument the Weather Bureau has for many years uniformly disregarded all corrections for mercurial thermometers less than ± 0.3°. This procedure is very questionable in the case of wet and dry bulb readings, for in this instance we often have to deal with a relatively small difference between two thermometric readings, and the amount of the difference is largely affected in some cases by the application or omission of the corrections for scale errors.

While the psychrometer is one of the most accurate and convenient instruments we possess for measuring the quantity of moisture in the air at ordinary summer temperatures, yet at and especially below the temperature where ice forms on the wet bulb good observations can be obtained only with difficulty and great care. The psychrometer in fact is hardly a satisfactory instrument for moisture measurements in cold winter conditions. Better apparatus is needed for this purpose, and here is a field for our inventors. This is one of the problems I have to offer for solution—the invention of a substitute for our psychrometer. In connection with this problem it is important to consider the nature of the difficulties we must overcome.

At the freezing point a cubic foot of saturated aqueous vapor weighs only 2.1 grains and its gaseous pressure is only 0.18 of an inch. At zero Fahrenheit it weighs but a trifle more than one-half of a grain and its pressure is less than four one-hundredths of an inch on the barometric scale. In the atmosphere these very small quantities of moisture are intimately mixed with very large quantities of air, thus adding difficulties to their measurement; that is, at the freezing point the moisture is mixed with about 270 times its weight of air, while saturated air at *zero* contains only one part of moisture in a thousand. Our problem, then, is to invent apparatus that will easily measure not only these relatively small portions of water vapor, but that will measure also the varying percentage of saturation that may obtain in different cases. These minute quantities may seem unimportant. We must remember, however, that they are the source of all our winter clouds and snowstorms. When we direct our attention to these considerations, we need hardly be surprised that the ordinary psychrometer fails to give good observations at low temperatures. Indeed, we may justly wonder that good results at all are obtained.

I can hardly leave our question at this point without asking your careful attention to a wholesome lesson in making psychrometric observations in winter that is to be drawn from the facts I have just presented. You all know that the cooling of the wet or ice-covered bulb is due entirely to the evaporation of a portion of its moisture. Now, when we consider that a cubic foot of air, even when raised to complete saturation, can carry away with it at low temperatures only a fraction of a grain of moisture we see at once that the cooling process acting on the wet bulb is a very feeble one. All the surplus heat in the mercury and bulb of the thermometer must be carried away by this very slight evaporation. Relatively a long time, therefore, is required to cool the wet bulb to its minimum temperature. Wet-bulb thermometers for low temperature determinations should have very small bulbs. This, however, introduces other difficulties of more or less serious nature which cannot be discussed now.

We need not only a substitute for the psychrometer for low-temperature work, but we want also a good form of self-recording hygrometer. The hair hygrometer has been exhaustively studied in Europe, and a fairly good recording form is quite extensively used in certain sections. We have not found it suitable for our needs, for several reasons. In the first place, the hygrometric action of the hair is comparatively sluggish, so that changes of state as regards moisture take place somewhat slowly. Its indications are inexact, so that errors of 5 to 10 per cent are hardly to be avoided. It is especially unreliable at high humidities. Finally, the dusty, sooty atmosphere so characteristic of the large cities at most of our stations soon soils the hair and greatly impairs its hygroscopic properties.

Thermographs and telethermographs.—The subject of thermometers is incomplete without discussing the thermograph and telethermograph; but time is not available for this now, and I will only remark that instruments of this class fail more because of occasional accidental defects, the complete interruption of the record, and gradual serious deterioration than because of actual errors, strictly so called.

Precipitation gages.—Mechanical processes of manufacture enable us to construct gages for the measurement of precipitation that are far more accurate than need be; that is to say, once collected we can measure the catch of rain or snow with any desired degree of precision. The trouble is to catch the rain or snow. The problem of the rain gage is a problem of exposure, not of measurement. The difficulty in exposure is the wind. If there is no wind, any exposure in the open is a good one. If the mouth of the gage is exposed to the wind, the catch is sure to be deficient. What we must do is to screen and shelter the gage as far as possible from the force of the wind; that is, while we freely expose it to the sky we must secure a perpetual calm around the gage if we are to hope to obtain a true catch. Without further comment upon the problem of the rain gage, I shall ask your attention next to the anemometer.

Anemometers.—The velocity of the wind is scarcely deducible, a priori, from the indications of any one instrument. The evaluation of the indications of the Weather Bureau anemometer rests upon relatively scanty and insufficient data over a very limited range of velocities. Errors of large magnitude are made in all our computations at high velocities—that is, from 50 to 100 miles per hour. We have a somewhat peculiar case here. The instrument itself, if fairly employed, is extremely accurate. The errors are caused by the lack of test observations at high velocities. We do not know how to connect correctly the movement of the cups with the measurement of the wind at velocities above 40 or 50 miles per hour. The problem of standardizing the anemometer at high velocities is by no means a simple one, but there are no special difficulties in the work. It is simply a question of a little money and the time and opportunity to carry on the necessary observations.

An erroneous impression prevails in the minds of some that the friction in the bearings and the back pressure of the wind on the convex cups are causes of error in the anemometer. This is by no means the case. Whether the friction is serious or not depends upon its magnitude with respect to the driving forces. Experience shows that it is easy to make the friction quite negligible compared with the driving forces. This assumes a reasonable care of the instrument; we also exclude feeble winds under 1 or 2 miles per hour. These are of very little meteorological importance.

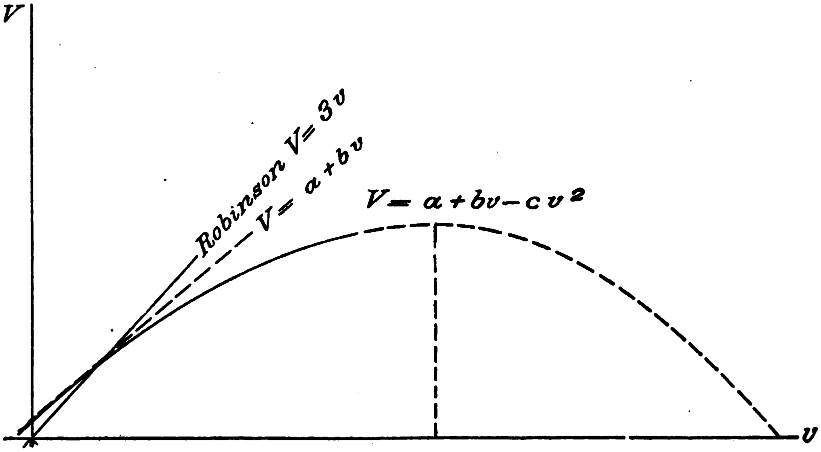
The back pressure on the convex cups simply lessens the equilibrium speed of rotation. There is a definite and constant relation between a given speed of the wind and the corresponding velocity of rotation of the cups. Our problem is to find this relation at all velocities of the wind.

The following results of six months' comparisons between two anemometers, one of ordinary construction and one with almost frictionless ball bearings, show very forcibly the insignificant effect of the ordinary instrumental friction:

	Miles.
The ball-bearing anemometer showed a movement of	31, 600
The anemometer with ordinary bearings	31, 554
Difference	46 (or 0.10 per cent.)

The instruments were given exactly the same exposure, on a lofty support. To eliminate slight differences due to the cups, these were frequently interchanged. The instruments themselves were also interchanged in position to equalize slight possible differences in exposure.

A few minutes may be well spent at this point to consider what we know of the anemometer law. Referring to the diagram (drawing on blackboard), Robinson, the inventor of the anemometer, was first led to conclude from his studies that the cups moved one-third as fast as the wind. This gives the straight line through the origin as shown in the following figure:



Later experiments led to the adoption of a straight line equation of two terms: $V = a + b$, also a straight line as indicated in the diagram, but not passing through the origin. A still more careful study of the problem showed that a quadratic equation fitted the observations still better. This is shown in the diagram by the curved line. From our present knowledge it is absolutely certain that both straight-line laws give too high velocities above 40 or 50 miles per hour. The great trouble is that scarcely any tests have been made at high velocities, and when these lines and curves are fitted to the observations at moderate velocities their extensions to high velocities lead to false or even absurd results. This is strikingly illustrated as follows: The quadratic equation which best represents the Weather Bureau tests at velocities up to 35 miles per hour is:

$$V = 0.263 + 2.953\,v - .0407\,v^2.$$

This equation agrees very closely with the observations throughout their limited range, but let us see to what absurd conclusions we are led by an extension of the curve to high velocities. This is shown by the dotted portion of the curve, and its character signifies that 53.7 miles per hour is the highest velocity the cups can indicate. A still higher cup velocity would mean, according to the equation, a lower wind velocity, and a cup speed of about 75 miles per hour would indicate a dead calm.

These and other absurd deductions are logical results from an unwarranted extension of the curves beyond the region of actual experiments. This extension is literally made in one form or another, nevertheless, every time we have wind observations above 40 to 50 miles per hour.

The problem presented by these considerations is not one of the invention of an instrument, but rather the problem of finding out how to interpret at high velocities the indications of the instrument we already have. I can not conceive of a better place than Mount Weather at which to take up systematically and seriously this much needed study. The power plant forms the nucleus around which the necessary apparatus may be gathered.

Sunshine recorders.—The last question I shall now attempt to discuss is the measurement of solar heat—that is, sunshine. This all-important factor in agriculture and cosmic meteorology can not be said to be measured at all at the present time—that is, in ordinary meteorological work. It is true we have the photographic, the electric, and other sunshine recorders, but these scarcely tell us with accuracy whether or not the sun is actually shining. They do not and can not measure its radiation in any true sense of the word. The crudeness of these devices is well shown, I think, by an illustration that occurred to me a few days ago while talking about sunshine recorders with a gentleman now present at this convention. I hope he will pardon this repetition.

Suppose we had no such things as thermometers and did not know how to measure temperature. It is plain, however, that if we set up a block of ice in the open air it would melt and we could see the water dripping from it as long as the temperature was above 32°. At and below 32° the water would not drip. We could, therefore, learn from this device whether the temperature was above or below the melting point. The methods at present employed for observing sunshine in ordinary meteorological work are even more crude for the purpose than this ice-block thermometer.

What we want to know is how many units of solar heat are received on a given surface from hour to hour or from day to day, just as we now observe the hourly motion of the wind or measure how much rain falls hour by hour. Apparatus for this purpose actually exists, but it is either nonrecording or of such elaborate and delicate character as thereby to exclude it entirely from the list of ordinary meteorological instruments. The problem I would offer in the present connection is to invent new and simple forms of continuously recording pyrheliometers that shall give the amount of solar radiation in thermal units per minute or hour, or the adaptation of old forms to the purpose. There is little doubt but that we shall see apparatus of this sort in regular use in the future, just as thermographs, barographs, etc., which were unknown fifty years ago, are now common everywhere. The problem is too extensive to discuss in detail now, and I can only give you this glimpse of its real character.

In concluding my remarks I want to say that from the very nature of my paper I have had to lay great stress upon the weak points of our apparatus. I do not want anyone to understand me to mean that everything is erroneous. I am obliged to make some of the faults strikingly conspicuous in order to encourage the invention of remedies. I want to say also that the problem of the hygrometer, the problem of the anemometer, the problem of rain gages and sunshine recorders, and others are each and all appropriate subjects of research for Mount Weather, and I am sure all will join me in urging upon our chief that no time be lost in taking up such lines of work. These things have to do with the everyday needs of our service. It is not sufficient to authorize expenditures and assign the work. The most important thing is to give the men who are assigned to the work the leisure from other duties and the assistance necessary to develop and work out their problem.

At the conclusion of the reading of the foregoing paper, Mr. Oberholzer exhibited and explained a shading device of his own invention, for use on the sunshine recorder, by which insolation is equalized somewhat.

LONG-RANGE WEATHER FORECASTS.

By Prof. E. B. GARRIOTT, *Washington, D. C.*

This paper supplements a recently prepared discussion of long-range weather forecasts in which the literature of the subject was reviewed and opinions of leading meteorologists regarding the practicability of long-range work were quoted. The sum of the evidence was that man has not yet acquired a knowledge of the physical laws of our solar system that will permit him to calculate on a demonstrable basis the character of the weather for specified localities for periods greater than two or three days in advance.

Theories regarding weather periodicities that are dependent upon lunar or planetary influences were pronounced theories of faith and not of practice, and the conclusion was reached that extensive research in solar physics and terrestrial magnetism and comparison of solar and terrestrial phenomena will be required in the next advance in meteorological science.

It is known that the general character of the seasons of the year is due to the influence of the sun upon the earth during the latter's annual journey around the center of our solar system. It has been assumed that if the solar influence were invariable the character of the several seasons would be uniform. As the character of the seasons is not uniform from year to year, we are led by the assumption to conclude that variations in the solar influence are responsible for irregularities in the character of the seasons, and that the nature of the variations and their association with terrestrial phenomena must be defined before material progress can be made in the theory and practice of long-range weather forecasting.

Solar physics investigations heretofore conducted for meteorological comparison have been confined principally to sun spots. In the future they will include observations of prominences that encircle the solar disk.

Sun spots and prominences have been compared to terrestrial cyclones and anticyclones. The character of the solar and terrestrial circulations is, however, very different. Sun spots are disturbances that are carried along with the solar circulation, and to this extent they may be compared to terrestrial cyclones. Prominences are waves of flame that are shot out from the solar atmosphere.

The energy of sun spots and prominences comes from the sun, while that of terrestrial cyclones and anticyclones is derived from a source that is exterior to the earth and its atmosphere.

We will now briefly summarize what has been accomplished by comparisons of maximum and minimum sun-spot periods with the phenomena of the earth's atmosphere.

The first investigations in this direction appear to have been made in India for the purpose of securing evidence of a connection between eleven-year periods of maximum and minimum number of sun spots and the quantity of rainfall. The sum of the evidence is that the connection has not been satisfactorily defined.

It is improper to conclude, however, that variations in the solar intensity are not connected with terrestrial weather changes. We will conclude, rather, that a connection does exist which can not be fully defined owing to a lack of evidence, and that the case will be subject to reconsideration when additional evidence shall have been secured.

The evidence to be secured will consist of a collection, for comparison, of a greater number of observations of solar and terrestrial phenomena made, not in India alone, but in observatories throughout the world. Meteorology has passed the limits prescribed by local services, and meteorological advance rests upon a systematic and most intelligent consideration of the world's atmosphere as a whole, and of extraneous causes that influence or dominate its phenomena.

One of the general results of sun-spot investigations is the establishment of the fact that terrestrial mean temperatures, at least in the eastern tropical area, are higher near the minimum of sun spots and lower near the periods of their maximum numbers. These results are confined to the lower stratum of the air and are, moreover, relative, as more heat is emitted from the sun during the period of maximum and less heat during the period of minimum of sun spots. The explanation of this apparent paradox is found in the preponderance of water surface in the earth's tropical regions. During periods of excess in the solar output of heat evaporation is unduly promoted over this vast water area, which results in an increased amount of cloudiness and rainfall. The atmosphere overlying the Tropics becomes vapor laden to an unusual degree and blankets, as it were, with a lower stratum of abnormally moist air, the surface of the earth from the rays of the sun. The moister air also, without doubt, contributes to a more frequent development of tropical storms.

The investigations also appear to show that variations in atmospheric pressure are related, with temperature and rainfall, to the maximum and minimum periods of sun-spot numbers, and that there is a transference of the atmosphere between two hemispheres of the globe, one of which includes Europe, southern Asia, India, Africa, and Australia, and the other North and South America and Siberia, which has a period of about four years or less on the average. They also make prominent the fact that upon atmospheric pressures depends the strength of atmospheric currents, and that upon the strength of the atmospheric currents depends the rainfall. The relation between the air currents, monsoons, and rainfall in India is conspicuously shown, and the fact is recognized that a determination of future distributions of atmospheric pressure is essential to predictions of Indian rainfalls and droughts.

Assuming that the Indian records indicate in a general way that periods of sun-spot maxima are periods of strength in the monsoon currents and abundant rains and periods of sun-spot minima are periods of weakness in the monsoons and of a dearth of rain in the Eastern Hemisphere, it should follow that these conditions respond to a certain distribution of atmospheric pressure, due to solar influence, that dominates not only the Indian Oceanic area, but a great part of the whole of the earth's circulatory system. It should follow, also, that a reverse of the conditions experienced in the Eastern Hemisphere will be found in the Western Hemisphere. In other words, that excesses of pressure, temperature, or rainfall in one hemisphere should be balanced by deficiencies in the other hemisphere. It is quite likely, however, that geographical areas affected by solar variations will appear in belts and not in hemispherical divisions, and that periods of sun-spot maxima, which are supposed to be periods of increase of solar intensity, will be associated not only in the Tropics, but in the middle latitudes, with increased activity on the part of the phenomena of the atmosphere. It is believed, in fact, that future investigation will show at all times a balance in the distribution of meteorological elements over the surface of the earth, and that during periods of solar activity storms are more frequent and alternations of periods of high and low temperature and rain and fair weather more rapid and marked than during periods of comparative solar inaction.

The evidence afforded by observations taken during the notable 1892–1902 period in the Indian Oceanic area shows that during 1893 and 1894, about the period of sun-spot maximum, the rains in India set in about the usual time, continued later than usual, and were abundant and persistent. From 1895 to 1902, however, which period covered the diminution and increase in the number of spots that attended the period of minimum numbers, the most disastrous drought in the history of India prevailed, and included a great part of Africa and Australia, or the area that depends for its rainfall upon winds coming from the Indian Ocean. It is important to observe, also, that while the East was suffering from drought England experienced year after year shortage of rain, and that when the eastern drought gave way in 1903 England had plenteous rains.

In the United States the period 1892 to 1902 was generally deficient in precipitation in the central and eastern districts. In 1892, 1893, 1895, 1897, and 1898 the temperature averaged generally below the normal, and the temperature averaged above normal in 1894, 1899, 1900, and 1901. In 1899, however, exceptionally severe cold waves occurred in the early part of the year, and in 1902 the departures above and below the normal were marked and irregularly distributed. Although 1898 shows temperatures below the normal, it will be remembered that the summer of that year was one of the hottest on record over the eastern portion of the United States. The summers of 1895, a cool year, and 1900, a warm year, also produced periods of excessively high temperature over the eastern part of the country. And the year 1903 was cold over the eastern half and warm over the western half of the United States. Weather Bureau records show that extremes of temperature and precipitation usually find compensation within the limits of the United States. When excesses of temperature or precipitation are experienced in the eastern districts a reverse of these conditions is almost invariably found over the western part of the country. It appears, therefore, that if variations in the solar energy have a hemispherical effect upon weather conditions the Rocky Mountain range must form approximately one of the division lines of the hemispheres.

The complexity of the whole subject is further illustrated by the result of observations taken in Europe and America in 1902 and 1903. In 1902 there was an increase of solar radiation, while in 1903, attending a nearer approach of the sun-spot maximum, a diminution of solar radiation was shown at a number of observatories It has been suggested that the opacity of the atmosphere in 1903, which was thought to be responsible for this effect upon some of the instrumental records of solar variations, may have been due to dust, possibly from the Mount Pelee eruption of the preceding year. It is evident, on the whole, that observations of solar phenomena should be taken at points that are least likely to be affected by impurities in the atmosphere. As conditions that are peculiar to the moister regions of the earth have been found to change the sensible effects of increased solar radiation, it appears necessary, on the score of accuracy, to establish observatories at the greatest possible elevations and at points that are not swept by winds from the oceans. They should be established in regions where the air is pure and dry. Solar observations taken under these conditions must be compared with observations of terrestrial magnetism and world-wide meteorological observations and their relations determined before light can be thrown on the problem of long-range weather forecasting.

We have now hastily reviewed results of comparisons of maximum and minimum sun-spot numbers with meteorological phenomena of limited portions of the earth, and have found only general and ill-defined relations. In the Indian area, where observations have been carefully made for many years, the results have been encouraging, but are insufficient for a forecasting basis. They have shown a general relation between sun spots and weather, the definition and application of which rest upon future observations and comparison conducted over much greater areas.

The means of accomplishing a world-wide plan of observation is receiving the serious consideration of scientists. The British Association for the Advancement of Science, at its meeting at Southport, England, in 1903, considered plans for a systematic study of the problem. The difficulties that would be met in attempts to coordinate meteorological data with results obtained in other lines of investigation were recognized, and ways and means for surmounting the difficulties will be considered at the 1904 meeting of the international meteorological committee. The amount of labor involved presents the principal and probably an insurmountable obstacle to an early achievement of results, and future advances will probably depend upon the collection and compilation by individuals or by individual observatories or services of world-wide observations of solar and terrestrial phenomena.

Recent discoveries in solar physics and improvements in instrumental appliances for making solar observations and the conviction that the world at large demands an improvement in the practice of predicting the weather, lead to the belief that progress will be much more rapid in the future than in the past, and that the time is not far distant when the increasing demand for an improvement in forecasts made for one and two days and for seasonal forecasts will be met.

One of the recent discoveries that promises to be of value in forecast work is that made by Dr. J. J. Thompson, professor of experimental physics at Cambridge University. He assumes from laboratory experiments that radiant electricity is projected from the surface of the sun, and that when this form of electric energy, called for convenience " electrons," reaches the earth it assumes an active part in the production of the various phenomena of the atmosphere. During their passage through the atmosphere the " ions " become nuclei for the condensation of water vapor, and thus produce rain. He found, also, that condensation takes place more readily on the negative than on the positive " ions," and that the former are carried down to the earth by the rain, leaving positive " ions " behind, thus accounting for the positive electrification of the upper atmosphere.

The extent to which this discovery can be utilized by meteorologists is dependent upon the relation that sun spots and their periodicities bear to variations in the amount of radiant electricity that is projected from the surface of the sun. If during periods of unusual solar activity, as represented by the maximum sun-spot periods, there is an increase in radiant electricity, as represented by "electrons" or "ions," storms should be more frequent and severe over at least a part of the earth's surface, and if the rhythm of the solar periods of maximum intensity can be determined and the relation of these periods with terrestrial phenomena can be fixed, we will be in a fair way to the accomplishment of calculations, not forecasts, of weather for future periods. In this direction, as in others, results can be achieved only by an enormous expenditure of time and labor. And the matter resolves itself into the question: By whom or under whose auspices will the necessary work be performed?

Notice has recently been made of a new spectro-heliograph of the Yerkes Observatory, which promises to be of exceptional value in solar research work. The instrument is a development of spectroscopic devices by means of which solar prominences can be observed and photographed, and it is employed in connection with the great Yerkes refractor of 40-inch aperture. If by means of this instrument changes in the activity of the sun and the distribution of elements on its disk can be accurately noted, the results will be valuable. The full necessities of the case require, however, similar observations at widely separated stations.

The problem now presented to meteorologists deals with the forces of gravitation and radiant heat, light, and electricity, and the conveyance of solar energy through space to the earth. Like other problems in scientific research it presents theory before facts, and present theories regarding the influence of solar upon terrestrial phenomena must in time yield to facts or be discarded in the light of new discoveries. The fact that sun spots are associated with terrestrial weather has been partially established, but the process of the physical action of variations of solar intensity in the production of weather changes and types presents a problem to be solved.

At 1 p. m. the first session ended.

SECOND SESSION.

Called to order at 3.05 p. m., 20th, by Professor Moore.

The Chair. The last paper was by Professor Garriott, on "Long-range weather forecasts." Perhaps some of you would like to say a word on the work of the long-range weather forecaster. As you know, it has been the policy of the Central Office to endeavor properly to educate the people as to the limitations of weather forecasting. There are many of these long-range forecasters who are deriving considerable profit from their work in the making of long-range predictions. This brings discredit upon the science of meteorology. It is a positive injury to the industries of the country, because there are many people engaged in business who do base their operations upon the work of these long-range charlatans. Their work is becoming of so extensive a character that I would like to urge upon you to put forth your best efforts to correct in the public mind the erroneous impression that these people have succeeded in diffusing. I think there has been considerable improvement made already, but make it a point always, when you lecture or speak or write, to educate the people to the fact that at the present time no one can make long-range forecasts upon a scientific basis. We hope the time may come when we can make seasonal forecasts, but it will never come through the work of the long-range charlatans who sell their stuff to a syndicate of newspapers. I would like to hear if anyone has observations to make along this line.

Mr. Smith, of Columbus. I would like to add to the words Professor Moore used, "When you lecture or speak or write," the words "when you visit." I have adopted the plan, when I go over Ohio, of inquiring whether any of the newspapers publish long-range forecasts, and if they do, to visit the men in charge. Much of the time you can convince such a man he has made a mistake. I take along one of the long-range forecasts, and it is a very unreasonable man you can not convince in an hour of the foolishness of it all. If you convince such men as you go about over the country, you will accomplish a wonderful amount of good.

Mr. Cox. In Chicago none of the papers has referred to these long-range forecasts, and I have never taken any means of advising them to say anything about these forecasts. I thought I was serving the Bureau in so doing, because it seemed to me that no attention should be called to these predictions. I am simply speaking of the Chicago daily papers. They never make reference to these forecasts. In such cases do you not think it advisable to make no reference to these forecasts? Is not the best good secured by avoiding all reference to them?

Professor Moore. That is the policy we pursued for a good many years, until they began to spring up like a mushroom growth, prosper, and grow rich and fat on the proceeds of their work. It is our opinion that the time has come for this Bureau to speak out in no uncertain tone. We must not attack an individual, we must attack the system; but the system you can excoriate as severely as you like. A few articles on the fallacy of the longe-range forecast published in the press of Chicago would have a far-reaching effect. It might prevent the publication of their forecasts in some of the rural papers. Almost anything that you section directors might say along the line of weather forecasting, if sent to the rural papers that publish your bulletins, would be used by them. You must be temperate in your expressions. Some section directors have had a very thorough distribution of the articles they have written against long-range forecasts and have had them printed in practically the entire State press. But they are very few in number. I would call your attention to this matter. It is one of the ways in which you can perform a public service by informing the people correctly.

Mr. Berry. On Saturday of last week—less than four days ago—I saw in a city not far from Chicago the forecasts of a certain long-range forecaster printed in most conspicuous manner, the headlines being in bold type and of brilliant color, the whole surrounded by an ornamental border, while beneath it in the same column was placed, with no effort at display, the official forecasts of the Weather Bureau.

Both the long-range forecast and the official forecast were telegraphed from Washington.

Mr. **Blythe**. I have not had a great many opportunities for talking about long-range forecasts in the State of Indiana, but in Indianapolis I have taken advantage of every opportunity, and I have been watching for several months past to get a special opportunity for an interview with a reporter with the distinct purpose of having that interview published and then distributing it through the rural press. The convention afforded me that opportunity, as I reported officially to the Central Office, and since I arrived here I have received a clipping from an Indianapolis newspaper giving the substance of the interview. I left instructions with my assistant to distribute copies of the interview to all the newspapers in the State, with the request that they take editorial cognizance of it.

Mr. **Chappel**. We have not made very much noise about long-range forecasting, although Mr. Sage and myself have worked quietly, and Mr. Sage in his institute work has always taken pains to explain the method of the Weather Bureau and the fallacy of the long-range forecast; and I believe he has done a great deal of good in the State. Most of his lectures in the institutes have been printed in the country press and have been given wide circulation. This work has been going on for several years, although the policy of the Central Office almost prohibited active work along that line.

Mr. **Jennings**. We took this matter up before the United States Weather Bureau did. There was a man in Kansas who used to publish a little pamphlet about the size of our convention programme. He sold it for a dollar. The ———, one of the most extensive publications in that line in the West, finally took him up and made him editor of their meteorological column, as they called it, so they could rake in more dollars; and they did. It was an advertisement for them. I got a communication from a man in Boston asking me about this Mr. ———'s forecasts and what I thought of them. I answered that I thought them fakes. He was not satisfied, and replied: "If these predictions are fakes, it is good business for you, as head of the Kansas weather service, to expose them and not allow him to be raking in the hard-earned dollars of the farmers. If they are not fakes, it is time you got down off your roost and let Mr. ——— have your salary." Well, I charted his forecasts for a whole season, and as the weeks ran on I also charted the weather conditions as shown by the State bulletin and the national weather review. At the end of the season I studied the matter, took these two charts, and prepared an article which I read before the Kansas Academy of Sciences, then before the Kansas State Horticultural Society, and then before the Kansas State Agricultural Society, in which I exposed the fallacy of Mr. ———'s forecasts by the record of the weather that actually occurred. The result was he was dropped from the paper, his book could get no sale at all, and he left the State.

Doctor **Cline**. I am thoroughly in accord with the views that have been expressed with regard to fighting these fraudulent forecasts, and have never let an opportunity pass without calling attention to the fact that they were fraudulent. I have published matter from time to time, and though I have not given anything to the State press I will do so. But I have seen no favorable allusions to any so-called long-range forecasts in any Louisiana papers. I attribute this to the fact that the people of Louisiana recognize that they have interests dependent upon correct forecasts of the weather, and they can find such forecasts only in the United States Weather Bureau.

Mr. **Marbury**. I think the nonpublication of these long-range forecasts is peculiar to the South. I have never seen such forecasts in the Georgia papers, or quotation from them or favorable reference to them. I delivered a lecture before the Georgia State Educational Association, in which I laid especial stress upon the fallacy of the long-range forecast, and my lecture was published almost in toto in the proceedings of that association. I have also had the portion of it referring to long-range forecasting published in the Atlanta Constitution.

Mr. **Bauer**. In corroboration of what Mr. Marbury says about the southern press not printing long-range forecasts, I would say that I have seen only one in a county or State paper of South Carolina. That was about two days before I left for the convention, and on the day following the report I made that I had never seen one. I think I can prevent such publication.

Mr. **Mitchell**. Some six weeks or two months ago we issued a letter regarding long-range forecasts, and since then we have sent out a circular conforming to the lines laid down by the Central Office. This has been distributed to the press, and the greater portion of the press will print it. I wish to make the observation that the damage done by these long-range forecasts is not confined entirely to crop conditions. They sometimes involve health. The day before I left Jacksonville a physician stopped me at the bank. A few days before that time there appeared in a daily paper, a very reliable, conservative paper, a forecast of this gentleman in the northeast—I forget his name. At any rate it was about the 5th or 6th it appeared, and about the 6th or 7th a tropical storm appeared off the coast of Florida. This forecast indicated that the whole southern portion of the country would be flooded. You can imagine the concern that was felt. This physician asked me why we permitted such things. He said he had a very ill patient who, until the time set for this forecast was past, was absolutely unstrung, and he thought she would really die. He thought it very essential that such frauds should be stopped, and he would try to see that that paper published no more of them. So we see the suppression of these long-range forecasts is not confined to us; we can enlist the sentiment of the most enlightened people in the community, and they will cooperate with us. By getting the cooperation of physicians who may have ill patients we can do a great deal along this line.

Professor **Moore**. Two or three years ago one of these long-range forecasters nearly depopulated Atlantic City. The Philadelphia Press asked me to give some reassuring word. The people were giving up their apartments and the hotels were unable to keep their colored help. I gave out a statement that there was nothing in it; no storm imminent; and still it was a fact that the day before the storm was predicted by this fakir many people abandoned their apartments and left the place. I had some correspondence with the editor of one of the Toledo papers recently, asking him if he would not join with the Bureau in our efforts properly to educate the people, and he wrote back to the effect that he admitted these forecasts were fraudulent and useless, but he said, " our readers want them." I did not answer him, but I might have said that the reader wants the kind of matter he prints, and he can educate his readers to almost anything. I think the best way to work will be for the section directors to write their opinions regarding long-range forecasting and send them out. It is the rural press you must give your attention to, although in a few large cities these long-range forecasts are published.

SEASONAL FORECASTS.

By Prof. ALEX. G. MCADIE, *San Francisco, Cal.*

The title is somewhat misleading, the object of the paper being to point out a possible way of improving the daily forecasts through the application of certain principles connected with seasonal conditions. It should also be stated that the writer does not know whether the methods herein advanced can be used advantageously in sections of the country other than the Pacific coast or India or where well-marked periodic " swings " of climatic conditions exist. It must be remembered, too, that these suggestions are made from the standpoint of the forecaster, who must do his work with such material as he has at hand and within certain limitations of time and area.

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In a certain city on the far edge of the continent it happened that the Chief Executive of the nation had promised to review the school children. The Weather Bureau office in that city is a large one. On the night preceding the date referred to the forecast was " Fair weather." Incidentally the senior forecaster said to the junior, "*That* map is certainly a fair-weather map." Next day it rained, and the 30,000 or more school children of the city, in their narrow judgment, doubtless thought that the forecaster did not know his business, although there had been a whole winter of very gratifying verification of forecasts. Experiences of this nature every forecaster has. Similar maps give unlike results. All map classifications are for this reason inherently weak and break down. On the other hand, lately and within this same forecast district, we have had the pleasure of saying " rain " and winning the forecast when every local sign indicated *clearing* and when the map itself to an ordinary eye indicated the passage of a disturbance and the advent of a " high " with probably clearing weather. This is winning when it means something to win and when the amateur prophets go down to defeat without consolation.

How is it done?

Pernter, in his paper upon " Forecasting the weather " (a lecture delivered in Vienna, January 14, 1903, before the Association for the Advancemtnt of Scientific Knowledge, and translated in Monthly Weather Review, December, 1903), insists upon the more thorough investigation of every phase of the distribution of atmospheric pressure. This is exactly what we are trying to do by studying the individual disturbance in its relation to the seasonal disturbance, if such relation exist. Some have tried to correlate drought periods in the *corn* belt with the paths of storm centers (see Monthly Weather

Review, January, 1904, p. 26), and the editor of the Monthly Weather Review points out that—

> as far back as 1872 it was the custom of the Weather Bureau for the forecaster who went off duty at the close of any month to explain to the one who relieved him that recent maps had shown that the general movement of the centers of low pressure was faster or slower and farther north or farther south, etc.

This, while desirable, does not go far enough. Instead of noting oscillation of mean storm path, would it not be better if all district forecasters were keenly alive to seasonal abnormalities, and particularly to all indications of impending change in position or energy of the so-called permanent pressure areas affecting their district? Hoffmeyer, Teisserenc de Bort, and others have shown that the position of the permanent pressure areas over the North Atlantic determines largely the character of the seasons in northern and central Europe. Eliot, Blanford, and others have shown a relationship between the weather of India and the great pressure movements. Fassig has traced the agreement between stormy Marches on the Atlantic seaboard and the movement of the continental and Atlantic high. On the Pacific coast the writer has tried to show in "Bulletin L" that typical wet winters in California occur when the North Pacific low extends well eastward, overlying the continent west of a line drawn from San Francisco to Calgary.

If I understand Professor Bigelow's theory of the structure of cyclones, the daily disturbances shown on the maps are brought about by the counterflow of great air streams. I think he has called them by-products of the great air streams around the world, and has shown that the excess of energy of the general cyclone is transformed into the driving forces of local circulations (Monthly Weather Review, April, 1902, p. 171). And again "that the rapid eastward drift is retarded by mechanical inflows from above toward the base of the anticyclone, and from below through the stream lines of the cyclone into the eastward drift."

It will follow then that the apparent place of development of the "low" or the "high" (the "high" being really the more important feature for the forecaster to study), the rate of transmission of the disturbance, and the path will vary under different seasonal conditions, although the period of the year be the same, or, in other words, will vary with the swinging northward or southward of the larger air streams. It has been claimed that the path coincides nearly with the trend of the isobars at an elevation of 5,000 meters. If the forecaster had a series of maps showing the isobars at different levels for each month similar to maps 37 to 43, "International cloud observations," and could detect any variation in the great polar low or its southerly extension, he would have some clue as to the probable character of the weather for two or three weeks impending. On the Pacific coast we know that when the surface isobars for the month are low, the season is one of frequent and heavy rains. Our presumption is that whenever during a winter month the polar oval swings far southward, California has an unusually large number of daily disturbances, and that under such conditions one must expect a quick return of a disturbance, notwithstanding any temporary rise in pressure or other surface indication of clearing weather.

Garriott (in Monthly Weather Review, June, 1902) has shown that the general atmospheric conditions over the United States associated with unseasonable weather are in turn associated with conditions obtaining over at least a great part of the Northern Hemisphere.

Of course we can not yet cover the entire Northern Hemisphere, and it is more than probable that when we attempt to put the scheme into operation we shall find that we can not begin to trace the whole chain of sequences; but the attempt might be made to utilize knowledge of seasonal abnormality. Any stoppage or stagnation in the procession at one point must mean a throwing out of step along the whole line. Suppose a forecaster feels sure that a "low" will be blocked in its eastern path by a stagnant "high." It is just the ability to foresee the stoppage which makes possible good forecasts of hot waves. The stagnant "high" is itself only an indication of a let-up in the normal interchange of air from the great air streams. The normal circulation becomes abnormal. The abnormality will bring about certain changes in the development, path, and velocity of the "highs" and the "lows." The forecaster must be quick to notice the change which gives character to the season. The daily map before him may seem to be exactly similar to another map; but if the general conditions governing the formation of the "lows" and "highs" be not similar, he must modify his forecast to meet the changed condition.

In California we have decided swings, or oscillations, in the so-called permanent pressure areas. We have marked dry periods in the heart of the rainy season and vice versa. As a rule the periods seldom exceed two weeks, though occasionally a marked set or seasonal trend is found to extend over six weeks. The individual disturbance is dealt with, then, in its relation to the seasonal trend, or, to be more specific, in its connection with the abnormal or unseasonal condition. There are, of course, great seasonal changes due to the annual motion of the earth, and these are shown clearly by our mean values. But in actual practice, the mean or normal seldom happens, any more than the ideal storm described in text-books ever appears on the daily map. If the forecaster may feel reasonably sure of one thing, it is that a season will not be a true normal. The abnormal, or unseasonable, is what we seek to forecast. And it is the early discovery of the causes tending to abnormality which will most improve the daily forecasts.

Two weeks ago, at San Francisco, weather reports were received, through the courtesy of the Chief of the United States Weather Bureau, from a number of European cities. At the same time reports were received from Honolulu and Manila covering, in all, 240° of longitude, from 120° east of San Francisco to 120° west of San Francisco, or two-thirds of the earth's girdle. I believe this is the longest stretch yet covered, and I think the first time in history when both the Atlantic and the Pacific oceans have been bridged. I hope the day will come when Professor Moore will get daily reports at Washington from a system of stations completely encircling the world. We hope he will be able also to persuade the various weather bureaus of the world to agree to an interchange of reports. With the practicability of wireless reports from sea areas now clearly demonstrated, the consummation of this long-desired work seems very near. With such surface reports we should be able to educe the conditions at levels of 1,000 and 3,000 meters, and, noting abnormalities over certain parts of the earth, trace the influence of such upon seasonable conditions elsewhere.

AMPLIFICATION OF FORECASTS FOR BENEFIT OF SHIPPERS OF PERISHABLE PRODUCTS.

By Dr. W. M. Wilson, *Milwaukee, Wis.*

Among the great industrial and commercial enterprises, which in their daily business transactions make practical use of the forecasts issued by this Bureau, it is believed that the shipping of perishable products stands second to none. A canvass of the daily weather maps issued for business purposes or a record of the calls for information of expected changes will show that the shippers of perishable products are among the most frequent, constant, and practical users of the weather service. This industry is not confined to any particular locality; it has no season of greater activity, but day in and day out, constantly the year round, its countless trains, laden with perishable products, are moving on convergent lines toward the great centers of population.

It is scarcely possible to gain any adequate conception of the money value of the perishable produce shipped in the United States in the course of a single year, but if we consider that portion of the living expenses of each individual represented by products of this character the enormous proportions of the industry become apparent.

Nearly all produce of this character is liable to injury from changes in temperature, and while shippers generally take all possible precautions to protect their shipments against conditions that might reasonably be expected at a particular season they must rely upon the Weather Bureau for warning of those sudden and extreme changes which call for extra precautions.

In discussing the relation of the Weather Bureau to this industry it is desired to call attention to the following points and if possible to offer some suggestions which may tend to render the service of still greater value to those engaged in the handling of perishable products:

(1) Do the forecasts as now issued fully meet the requirements of this industry?

(2) To what extent has the Weather Bureau specialized its work for the benefit of other and similar lines of industry?

(3) Is it practicable to amplify the forecasts so as to meet the needs of shippers of perishable products?

The shipper of perishable products is interested only in that portion of the forecasts which relates to expected temperature conditions, rain, snow, or wind being of minor importance unless of so unusual a character as to delay shipments.

The temperature at which injury is liable to occur differs for each individual product, conditions favorable to one being often injurious to another, so that there is practically no season of the year when the shipper of perishable produce may not consult the forecasts with benefit. In order to determine what classes of goods may be shipped or the precautions necessary for their safety the shipper must have a definite idea of the extremes of temperature to which his shipment will be subjected in transit, including the loading and unloading.

This he can obtain only from the daily weather map or the forecast. From the weather map he is able to obtain a general view of the current conditions over the district in which he may be interested, and if experienced in its use may even be able to make a forecast sufficiently accurate for his purpose.

From the forecast he obtains the judgment of the official forecaster as to the expected temperature at certain hours on the following day, but information as to the extremes of temperature to which his shipment may be exposed during the succeeding thirty-six hours is lacking. The forecast therefore fails to meet fully the requirements of the shipper, for the following reasons:

(1) The temperature element in the forecast, being based on expected changes from the temperature at 8 a. m. and 8 p. m., conveys but an imperfect idea of the degree of heat or cold expected during the period covered by the forecast.

(2) The values of the terms "colder," "warmer," etc., as used in the forecasts, are relative, and to reduce these expressions to a definite quantity requires a technical knowledge of "periods" and "verifying changes" which few other than Weather Bureau officials possess.

(3) The values of the terms "colder," "warmer," etc., vary for the different months in the year, which often renders the import of the forecast uncertain and at times confusing to the layman.

But, assuming that the shipper is fully conversant with "periods" and "verifying changes" and has sufficient time to study the forecast, he may be able, by applying the verifying change to the current temperature, to determine the anticipated change for the first period; but when the second period is concerned there is absolutely no way of predicating what was in the mind of the forecaster, except that he expected a change of 6, 8, or 10 degrees from the temperature at 8 p. m. of the current day. To obtain anything more definite, the shipper must make his own forecast of the temperature at 8 p. m. of the current day and then apply the change value.

(4) The forecasts of cold waves are equally open to criticism on the score of indefiniteness, the differing values for the different months and various localities being confusing, and here again the shipper must do some independent forecasting in order to obtain a definite idea of the degree of cold expected.

The practice which obtains with some forecasters of stating the minimum temperature expected and the time of its occurrence adds much to the value of the forecasts and should be required in all cases.

These criticisms are made solely from the point of view of the shipper of perishable products, whose interests demand a more definite statement of temperature conditions than is contained in the forecasts as at present issued.

The system of verifications now in use is certainly the best that has been devised for testing the comparative skill of forecasters, but the needs of the public are paramount to the convenience of the verifier and should receive first consideration.

The policy of the Weather Bureau to specialize its work so as to give to every line of industry the exact information it may have need of is shown by the different divisions of the work and the various suborganizations that from time to time have been incorporated in the national service.

The mariner has the storm-warning service; the fruit grower of Florida and California the extensive system of frost warnings; the agriculturist the climate and crop service; the southern planter the cotton-region and sugar and rice service, while the residents of our river valleys are protected by the extensive system of flood warnings. Each of these divisions or organizations has its own particular line of work and directs its energies toward a particular and definite object. There is therefore ample precedent for any special effort that may be made to amplify the forecasts or, if need be, to organize a system by means of which available information of expected changes may be conveyed to those engaged in the handling of perishable produce.

The needs of this industry may be summed up as follows:

(1) A forecast that states in definite terms the highest and lowest temperature expected during the period covered.

The shipper will be able to grasp the import of such a forecast at once without entering into a mathematical calculation involving "current temperatures," "periods," and "verifying changes."

(2) This industry, moreover, needs the forecasts for a larger territory than is usually furnished by the daily weather maps issued from the various Weather Bureau stations other than forecast centers.

Although large shipments are frequently in transit several days or even weeks, being under the supervision or control of a single individual, to whom a forecast for the entire country is indispensable, it is not to be expected or even desired that every local Weather Bureau office should be able to furnish such an official forecast, but every local Weather Bureau office should be furnished with and publish on its daily maps and bulletins the forecast for those contiguous States in which its local merchants are interested. It is the everyday shipper, whose produce may reach its destination within twenty-four or forty-eight hours, that is able to take advantage of anticipated changes, and his interest should be consulted in the selection of the territory to be covered by the forecasts published by the local office.

The amplification of the forecasts to meet fairly the needs of this industry would not involve the establishment of a new system, the organization of a new service, or a change in the present method of verification. It would simply mean the consideration by the forecaster of the extremes of temperature expected to occur during the period covered and the addition of a single code word after each State forecast to express his judgment. It might at times be necessary to divide the State into sections, as is now done, and make a separate forecast for two or more sections, but the additional time required and the expense involved would, it is believed, be slight compared with the benefits to the public at large, as well as to the shipper, to be derived from such additional information.

A forecast of this character would read: "Fair to-night and Tuesday; warmer Tuesday; minimum temperature to-night, 62°; maximum Tuesday, 84°."

Such a forecast conveys a definite meaning; its import can not be misconstrued; it is comprehensive and easily understood both by the expert and the layman. Moreover, the official forecaster has in mind a definite conception of the expected temperatures and the public is entitled to a concrete statement of his judgment.

DISCUSSION.

Professor **Moore**. I think Doctor Wilson has made a good point. The forecaster already has authority to supplement the forecast. That is really a function of the local forecaster—to amplify the State forecast. It is not necessary to issue additional instructions, unless we wish to compel such additional forecasts. You have ample authority now under the instructions to add to your forecast the expected minimum at night and the expected maximum to-morrow.

Professor **Abbe**. I think that it would be very well to indorse what you say, because I notice that a great many men simply repeat the Washington forecast and the country credits it to them as if it were their original work. Besides, to put this new item in, which is important to all farmers, makes the men feel more responsible for something. It would be a first-rate mental test for everyone.

Professor **Moore**. If you gentlemen who are here will make the trial a little later Professor Garriott will keep track of the work, and if the method results in an improvement we will probably adopt it later in general instructions.

AN AID IN FORECASTING.

By Mr. F. H. Brandenburg, *Denver, Colo.*

During the last thirty years a large amount of data bearing on weather changes has been collected, but it is not in such shape as to be available for personal investigation and classification. It would seem that steps should be taken to tabulate, currently, at the local stations, the more important features attending weather changes. When we consider the vast area and widely varying topography of the territory covered by these stations, their different altitudes and range of latitude, it is clear that without a convenient method of studying in detail their local peculiarities during each season the forecaster is at a disadvantage. Under present methods it is not to be expected that any one man should be perfectly familiar with a very large part of the country. For their particular stations, this knowledge is, however, common to all local officials, and there is scarcely a station in any State or Territory at which the meteorological phenomena have not been given careful attention at some time in the history of the Bureau. The fact that the local observers might contribute important material in this regard is appreciated by the forecast division, which collected, and has recently published, in Weather Folklore, valuable information along this line.

This was an excellent move, since, as is well known, the exigencies of the service necessitate the changing of officials in charge of stations. Even though no forecasts are made by the local official, he will, if observant and studiously inclined, accumulate much valuable information relative to the bearing of local signs on the coming weather. If the making of forecasts be added to his duties, he is the gainer in proportion to the interest previously taken in local signs. With his relief and assignment to another station, however, the knowledge acquired might not be of any direct value to him at a distant station, but to his successor well-tabulated data, if available, would prove of great assistance, enabling him in a very short time to take up the work where his predecessor left off. Our duty is to discover and utilize all that can be found out about the local weather for every station of the Bureau, and these investigations should form a part of the station records. By so doing an excellent foundation will be laid for improvement in the forecasts.

I would recommend the adoption of a monthly form on which should appear the following-described data:

Prevailing direction of the wind during the period 24 to 12 hours before precipitation sets in; prevailing direction during the 12 hours immediately preceding precipitation; prevailing direction of the wind during precipitation; prevailing direction during the 12 hours immediately after precipitation; amount and character of change in temperature at two observations preceding the beginning of precipitation; prevailing direction of the wind from 7 a. m. to 8 a. m. and 7 p. m. to 8 p. m., whenever the 24-hour temperature change equals or exceeds the verifying number of degrees; kind and direction of upper clouds during the period 24 to 12 hours preceding precipitation; prevailing direction of the clouds during the 12 hours preceding precipitation; pressure immediately preceding precipitation, whether practically stationary, rising, or falling; pressure during precipitation, whether practically stationary, rising, or falling; prevailing direction of the wind during a rise or fall of actual pressure equaling or exceeding 0.25 inch in 12 hours.

These values, which will be obtained principally from the automatic records, are sure to give valuable results, since they will not be mere impressions. Much of the information described is, of course, approximately known to the local officials and, in a general way, to the district forecaster. My idea is that the actual working up of the data will bring out points not generally observed, and that a study of the data will add to the accuracy of the forecasts. The report should be made out in triplicate on suitably prepared forms, a copy retained at station, a copy sent to the Central Office, and the third forwarded to the district center.

The objection may be raised that the work incident to the preparation of such a form is considerable. In my judgment very little time will be required, especially if the daily record of meteorological conditions be kept in the future as has been recommended. Among other interesting features, the compilation will bring out definitely the preponderance of a certain class of temperature changes during certain seasons, as, for instance, falls of temperature are pronounced during the winter months in the Plateau region, but a return to normal is exceedingly gradual, so that the changes to colder greatly outnumber the technical changes to warmer.

While a study of the classified weather types shows that similar distributions of pressure are for the most part attended by similar weather conditions, there are at times many local exceptions that are difficult to understand. It is these local exceptions that cut down one's percentage, and I for one will welcome the adoption of any plan that will put the district forecaster in possession of a definite knowledge of local signs. Even a slight increase in the percentage of verification is of great value and should be earnestly striven for.

DISCUSSION.

Mr. J. Warren Smith. I have begun the preparation of definite local rules for forecasting, and expect to forward a paper to the Central Office soon discussing this matter in detail.

It is apparent to me that there are certain well-defined rules in forecasting that can be determined only by a careful, systematic, and exhaustive study of the observations at each individual station—rules that one can not know without analyzing the data available and that one can not remember without referring to them occasionally.

There are other rules that have well-defined exceptions, and it seems to me that the study of these exceptions will prove of great value to a forecaster.

Of course in the present method of verifying the forecasts of a section of a State by individual stations, we must consider the weather at the station to typify the weather of that part of the State.

For example, during the month of July, at Nashville, Tenn. (my outer station), a " colder " morning has never been followed by either a " colder " or a " warmer " morning during the period for which I studied the records. Hence, if we have a " colder " morning before us, it is useless to predict either a " colder " or a " warmer " for the following morning. A " warmer " morning has never been followed by a " warmer " afternoon during July. During this month also " warmer " never accompanies a rain at night.

During the month of August, at Nashville, in the eight years discussed, " warmer " has never accompanied a rain at night, and " warmer " has never accompanied a rain during the day except during the passage of a West Indian hurricane. During this month a " warmer " morning has been followed by " warmer " the following morning but once, and a " colder " morning followed by " warmer " the next morning but twice.

If the current temperature is below normal, it has been " colder " on the following morning but twice out of 26 " colders." A current temperature above normal has been followed by " warmer " the following morning but twice also.

I am aware that it seems rather foolish to talk of forecasting by rule, but I see no reason why a rule that has held good for eight or ten years should not be a good one to follow.

REPORT OF BOARD APPOINTED TO CONSIDER THE REVISION OF METEOROLOGICAL FORMS.

Presented by Prof. Henry J. Cox, *Chicago, Ill., Chairman.*

The board appointed by memorandum No. 90, dated May 12, 1904, to consider the revision of the meteorological forms of the United States Weather Bureau, has the honor to report as follows:

The meteorological forms now in use may be divided, for the purpose of this discussion, into two classes. The first class includes Form 1001, meteorological, monthly record of observations, Form 1014, meteorological, daily journal, and the hourly record forms of temperature, pressure, wind, etc. The second class includes those forms which pertain to the work of the climate and crop service, special river and rainfall observers, etc. To the last-named class may also be added a large number of forms, temporary in character, prepared mostly for use in the various divisions of the Central Office and in the distribution of meteorological data to the general public. The great majority of the forms under the second heading are considered by the board to answer the purpose for which designed and do not therefore need revision. In regard to the first class, however, it is evident to the board that a revision can be made that will more fully meet the requirements of officials in charge of stations, and at the same time serve the purposes of the Central Office. After considerable discussion the board unanimously recommends as follows:

1. The adoption of a form to be known as the "daily local record." This form provides for the entry of the hourly temperature readings, the hourly amounts of precipitation with the times of beginnings and endings, the hourly sunshine, the hourly wind direction and velocity, and the hourly maximum wind velocities when above a certain limit, which limit will vary for the different stations. It also provides for entering the character of the day, the total sunshine in hours, prevailing wind direction, and other data, and a diagram is provided on which the daily temperature and pressure curves may be platted, if desired. Space is also provided for the entry of abnormal conditions, severe storms, and other matter not expressed by the instrumental readings. An extra horizontal column, without heading, has been provided for the entry of data of excessive precipitation (now recorded on the back of Form 1017, meteorological) or other data that may be of sufficient importance to retain at the station. In short, it has been the aim to embody in the daily local record form a complete history of the weather of the day. The daily local record will be retained at the station and will take the place, so far as the station record is concerned, of Forms No. 1026 (thermograph), No. 1021 (hourly wind direction), No. 1022 (hourly wind velocity), No. 1070 (hourly sunshine), and No. 1014 (daily journal).

The size of the daily local record form shall be the same as that of the pages of Form 1001, meteorological.

2. In the matter of compiling the hourly readings of the various instruments the board is of the opinion that sufficient compilations of the hourly barograph readings have been made, and it therefore recommends that Form 1026, meteorological (barograph), be discontinued on January 1, 1905, at all stations now rendering said form. In regard to temperature, the board is of the opinion that this element, aside from its purely climatic value, has sufficient public interest to warrant the tabulation of hourly values as at present, but after tabulations are made and means found for a period of twenty years, no further sums and means of the daily and hourly values need be made.

The hourly records of wind direction and movement are important, especially at lake and seacoast stations and at some points in the interior. Since frequent changes in the exposure of the wind instruments have been made in the past and since it is probable that such changes will continue to be made in the future, the matter of determining monthly and seasonal normals becomes exceedingly difficult. Each exposure of the anemometer forms in itself a separate and distinct record and should be treated as such. Unless a series of comparative readings are made between the old and new exposures a combination of the two series in a general mean is not satisfactory. Therefore when a removal is contemplated a series of comparative readings extending over at least a year should be made whenever practicable. It is believed that these data should continue to be tabulated as at present. At those stations where an undisturbed and continuous exposure has been had for a period of ten or fifteen years it is quite probable that fairly accurate normals could be obtained, and those stations might be authorized to cease computing sums and means.

3. Form 1001, meteorological. The board recommends the adoption of a new Form 1001, meteorological, and submits a sample form. The new Form 1001, meteorological, retains pages 2, 3, 6, and 8 of the present form substantially as they are. These pages, it may be remembered, provide for the 8 o'clock and special observations. The last-named page has been brought forward and takes the place of the instructions, which now stand on page 4 of the present form. Page 5 of the present form, "Wind, number of miles, and length of time from," has been stricken from the new form.

The board recommends that no further compilation be made of the data now recorded on page 5, Form 1001, meteorological, after December 31, 1904. The new form contains four additional pages, on which it is proposed to enter the hourly temperatures, the hourly wind directions and velocities, and the hourly sunshine. These four pages replace the present Forms 1026 (thermograph), 1021 (hourly wind direction), 1022 (hourly wind velocity), and 1070 (hourly sunshine). In other words, the board has consolidated with Form 1001, meteorological, four additional forms, and has thus brought together in compact shape information that is now carried on four different papers. The board desires to invite attention to the fact that the adoption of the above recommendations obviates the necessity of press copying the forms just mentioned.

The copy of Form 1001, meterological, retained at station, will contain only a record of the observations at 8 a. m. and 8 p. m. (75th meridian time), the special observations, and the summary of temperature and precipitation on page 9, except that the beginnings and endings of rainfall will not be entered on the last-named page. The beginnings and endings of rainfall will appear on the Central Office copy, however, in 75th meridian time, and the total precipitation there given will be for the period midnight to midnight, local standard time.

The board recommends that stations be given two additional days in which to complete and forward Form 1001, meteorological, to the Central Office.

4. Form 1002. The board recommends that Form 1002, meteorological, annual meteorological summary, be made the same size as Form 1001, meteorological, and the daily local record.

5. The board recommends that the daily local record be kept on loose sheets until the end of the year, and that it then be bound together with Form 1001, meteorological, and Form 1002, meteorological, in a single volume; that all three forms be printed upon light durable paper of uniform thickness and texture. Officials in charge of stations will then have in one volume a complete meteorological history of the year.

6. The board recommends that all instrumental records and the

daily local record be kept on *local standard time*, but that all data intended for the Central Office shall be recorded on 75th meridian time, except that the hourly temperature, the hourly records of wind velocity and direction, and the hourly sunshine shall be entered on local standard time.

7. The board recommends the discontinuance of the present form of daily journal and the substitution therefor of two forms for the special use of the Central Office, one of which shall contain a brief report of the administrative matters for the use of the chief clerk's office and shall be known as the monthly work report for chief clerk, the second to contain a description of unusual or remarkable atmospheric phenomena that have been observed during the month and any matters that seem to call for special mention. It is not the intention that entries shall be made for each and every day of the month, but rather that a succinct narrative be given of the important events of the month, such as the occurrence of severe storms, cold waves, thunderstorms, or the prevalence of abnormal conditions extending over several days. It is believed that a copy of the notes made for the daily local record will, as a rule, meet the requirements of the Central Office. This shall be known as the monthly meteorological report.

8. The board recommends that the following data be no longer recorded:

(*a*) Extreme wind velocity. This information is of doubtful value. It must always be accompanied by a statement of how it was obtained, and it is liable to be confused with maximum velocities for five-minute periods; moreover, when high velocities are attained it is difficult to read them accurately from the wind sheets.

(*b*) Number of days with mean temperature below 14° and 32° and above 41°, 50°, 59°, 68°, 77°, and 90°, as recorded in the summary of Form 1001, meteorological, Form 1002, meteorological, and the means book. These data have been compiled for a number of years. They have not yet been used, so far as known to the board, in any manner. They can be obtained, if desired, from other records, and it is therefore believed that time and space can be saved by discontinuing their further compilation.

(c) Snowfall on the ground on the 15th of the month. The board is unable to find that these data now serve any useful purpose.

9. Form 1030, meteorological, monthly meteorological summary. Slight changes are recommended in Form 1030, meteorological, namely, the addition of an extra vertical column to the right of the column headed " Character of the day " for the entry of daily snowfall, sunshine, etc., whichever may be deemed most important. The heading of this column should be left blank. Some slight changes in the summary are recommended so that the form will contain all the information needed at the climate and crop centers.

10. The board recommends that the means book be known hereafter as the climatological record. It further recommends that the manner of entering the data therein, or the form of the volume, be changed as follows: Instead of entering the several elements for each month consecutively on seven pages, as at present, let them be grouped under several general heads, as " Pressure," " Temperature," " Precipitation," etc., according to the character of the data, and entered separately. Thus under temperature the " Monthly mean

temperatures" will be grouped on a single page. This page will show the monthly mean temperature for all months of the year and for all years covered by the period of observation. In like manner all entries under pressure for the year will be segregated and appear on a single page.

The pages of the climatological record should be made the same size as those of the daily local record. This size will permit the entering of two elements on a single page; thus the highest and lowest reduced pressure will be entered side by side on a single page. The plan of the volume provides for the entering of forty years' record. The beginning of the record of each element should appear on the top of the even page and end at the bottom of the odd page, so that when the book is opened the entire record for forty years will appear on the open pages.

The board recommends the entry of the following information not now recorded in the present Means Book, viz: Daily maximum, minimum, and mean temperatures, daily precipitation, and daily snowfall. In addition to the daily records above mentioned the board recommends that the hourly means of temperature, wind, and sunshine, as entered monthly on the Washington Form 1001, meteorological, be transcribed on suitable pages in the climatological record, and that the observers copy into the climatological record said hourly means for previous years, so that eventually normal values for these elements may be obtained. When this is done a further compilation of hourly means may be dispensed with. Space has been provided on the pages of the climatological record for platting the diurnal curves of pressure, temperature, wind, and sunshine. In order to complete the climatological record the hourly means of pressure that have hitherto been compiled should be copied in the new volume.

Finally the board believes that the climatological record should contain the following data:

Pressure (reduced to sea level).—Highest, lowest, mean, absolute monthly range.

Temperature.—Monthly mean, departure from the normal; mean monthly maximum and mean monthly minimum; absolute monthly maximum and date; absolute monthly minimum and date; mean daily range, greatest daily range; absolute monthly range; mean monthly variability; lowest monthly maximum, highest monthly minimum; number of days with maximum 32 degrees or below, 90 degrees or above; minimum 32 degrees or below, zero or below.

Relative humidity.—Mean a. m. and p. m.

Precipitation.—Total amount for the month, departure from normal; greatest amount in 24 hours, amount and date; one inch an hour or over, total amount and date; 2.50 inches in 24 hours, amount and date; number of days with .01 or more, .04 or more, .25 or more, 1.00 or more; total depth of snowfall; number days with snow, snow on ground at end of month; greatest snowfall in 24 hours; greatest depth of snow on ground and date.

Wind.—Total movement; prevailing direction, average hourly velocity; maximum velocity, direction and date.

Weather.—Actual hours of sunshine, percentage; average cloudiness, a. m. and p. m.; number of days clear, partly cloudy, cloudy, with fog, hail, thunderstorms, auroras, solar halos, lunar halos.

Daily and hourly data.—Daily maximum, minimum, and mean temperature; daily precipitation; daily snowfall; hourly mean values of pressure, temperature, wind, and sunshine.

Extra pages have been supplied in case observers desire to tabulate any data not provided for in the above enumeration.

11. In order to facilitate the compilation of monthly data of tem-

perature and rainfall at the climate and crop centers the board recommends that a form similar to the sample submitted herewith be prepared at the Central Office and distributed to all climate and crop centers. This form may be used for compiling monthly mean temperatures, monthly extremes of temperature, or monthly amounts of precipitation. When a number of forms have been completed they should be bound for their better preservation.

Before closing this report the board desires to urge the importance of devising some method of recording the cloudiness at night and the beginnings and endings of light precipitation. The board recognizes the very great importance to stations of a retained copy of the wind sheets, Form 1017, meteorological. It is understood that as yet no means have been devised whereby such copies can be had. The hope is expressed that the instrument division of the Central Office may be able to take up the problem and eventually solve it.

The importance of determining the amount of evaporation, especially in the arid and subarid regions of the West, has been laid before the board. While it is probably not within its province to enter upon any formal discussion of the matter, it would seem that the best interests of the service would be subserved by instituting observations on evaporation.

Chicago, Ill., September 19, 1904.

Respectfully submitted.

(Signed) HENRY J. COX,
A. J. HENRY,
EDWD. A. BEALS.

DISCUSSION.

Professor **MOORE**. You have heard the report of this board. I am very favorably impressed with it as read. If objections appear to anyone in regard to any portion of the details as described, we should like to hear them.

Mr. **CHAFFEE**. Under the second portion of the report, the committee, as I understand it, has not taken up the combination of any substation forms. Now, as a section director, I have found it very annoying at times and very difficult to properly bind substation forms, on account of their being of different shapes and sizes. Some time ago the Central Office changed the style and size of the cotton region substation Form 1005, so that it conforms almost exactly to Form 1009, except that 1005 is printed in red instead of black. Now, I would like to amend the report of the committee by inserting, in the second part, that the present substation Forms 1006, "monthly reports of river observers," and the substation report known as 1010, "monthly report of rainfall observers," be made of the same size as Forms 1005 and 1009 and printed on the same kind of manifold paper as is used for those forms. My object is this: In almost every section there are a number of rainfall observers and river observers who take temperature observations voluntarily; they send reports to the Central Office or to their district centers on 1010. They also send reports of the temperature to the section center on 1009, and it is necessary for the section director to carefully compare them to see that he is publishing exactly the same data that are going to the Central Office. If these substation Forms 1006 and 1010 were made of the same size as 1005 and 1009, it would not only assist the work of the section director, by having them in triplicate each month, one copy to be retained at the substation and two copies forwarded to the district center, but it would reduce them to a common size, so that in binding the forms at the end of the year they will be in such shape that they can be conveniently handled.

Professor **Henry**. The suggestion of Mr. Chaffee was considered by me before I left Washington. The substitution of the manifold form was not looked upon favorably by those having direct charge of the forms. The only concession made was to consolidate Form 1010 with 1006, the river report. That will be done very soon. The other matter I am not so sure can be accomplished. There seems to be good reason for preferring the heavy paper form. But the suggestion is a good one, so far as uniformity is concerned. The board considered it.

Mr. **Emery**. Do I understand that Forms 1021, 1022, and 1026 are optional or required in Form 1001?

Professor **Cox**. These forms would be included in the Form 1001 to be sent to the Central Office. There are certain sheets in Form 1001 that do not appear in the station copy, because the data on these sheets will appear in the daily local record. The hourly values will be copied from it to Form 1001, so that the station will have all the data forwarded to the Central Office, except that it will have its hourly values in its daily local record, and thus a complete meteorological history of the day on this one sheet.

Mr. **Emery**. Then 1021, 1022, etc., appear on the daily record?

Professor **Cox**. Yes.

Mr. **Emery**. Are the forms sent to the Central Office to be compared?

Professor **Cox**. Something that does not appear in the report is this, that the data, as they are copied from the registers, are to be copied direct to the daily local record. That form will be an original record, or at least more like an original record than anything the stations have ever had. We have been bothered a good deal by that sort of thing. Generally it is an official record that is called for, but sometimes one is asked if it is an original record. Now, the Central Office, at Washington, will have all the absolutely original records. It will have Form 1083, but this daily record will more nearly approach an original record than anything the stations have ever had, because the hourly values will be first copied on the form and then transcribed from that form on Form 1001—on those pages of Form 1001 which have been set aside for the hourly records.

We considered in this discussion the necessity for discontinuing all press copies of forms. The Central Office not only sent out a circular, but the Chicago office sent out a circular letter asking for information from a great many observers. There were many objections raised as to the press copies of the daily journal and of the hourly forms. It was claimed that after five or six years they faded away and were no longer of value. A great many stations have been objecting to the manner of compiling the daily journal. Professor McAdie informed me that it took him nearly an hour one day to compile the daily journal. By our plan all the station need do in compiling the new monthly meteorological report is simply to prepare at the end of each month a summary of the special conditions that have prevailed during that month. There may be a period of a week or ten days at a time to which no special reference need be made, and then if a storm occurs, say on the 11th, 12th, or 13th, that storm would be covered. In other words, we expect to ask the stations to render only some such report, in this special meteorological report, as we have termed it, as will be of value to the Central Office. At present we send in a long report covering each day of the month, and the weather on many of those days is of no value to the Central Office. This special report will contain information of value, and it can be prepared, probably, in the time it now takes to write up two dates of the present daily journal, possibly one.

Professor **Moore**. Have you incorporated Mr. Seeley's idea of making one form that gives a complete history of the meteorological record of the day?

Professor **Cox**. Yes; we have. This daily local record has been kept at the Chicago station for two years and a half, with, I may say, great success. The daily local record this board has adopted is an improvement upon that form, but it is that form with a modification, and, as far as the Chicago office is concerned, I would like to say that we have made up that daily local record through the authority of the Chief of the Bureau, and he kindly consented to allow us to consider that the official record, in order that the experiment might be made. Although that was an extra form for the Chicago office, we have saved labor over and over again by its use, because in that book we have the whole record for day, month, and year; and whether you go to the telephone to answer a call, or go into court, or meet somebody who comes to the office, you take out this book and give everything from it. Only a short time before this board met I happened to answer the telephone myself and gave a man some data covering a period about three years ago, when we did not have this local record. I judged first from what he wanted that perhaps Form 1001 would answer. I got Form 1001 and gave him what I could from that, then had to go to the case and get two other books. In searching through these books I actually consumed twelve minutes of the man's time and my own. If I had had that daily record I could have given him the information in perhaps two minutes or less.

Mr. **Scarr**. May I ask, first, what authority this convention will have in discussing or passing upon the adoption of these new forms, and, second, if we have any authority in the matter, will it not be possible to postpone consideration of the matter, pending the placing in the hands of each member of this convention of copies of the proposed forms, that we may inform ourselves exactly as to what is wanted or intended or recommended by this committee?

Professor **Moore**. The report of the board will be approved unless something radically wrong in these forms can be shown. As to whether it would be advisable to get up samples of the forms and send them around for criticism, I doubt it, for the reason that we should probably get a good many conflicting ideas, and we thought that if we took one representative of the Central Office and two from the stations, choosing Professor Henry, who was Chief of the Records Division for so many years and is familiar with all the forms coming from the stations, and two men representative of the stations who were themselves familiar with the work of the stations, we should probably get a good consensus of opinions. At least it is hardly probable that these three men would leave out anything that is valuable or put in anything not valuable. So I doubt that we shall send the forms around for discussion. We may. We want to get these forms as nearly right as possible, so that it will not be necessary to change the method of compiling data for a good many years to come. I want to emphasize this: I am quite certain a marked improvement is made in the method of compiling meteorological data as a result of the work of this board, and I want to call your attention to the fact that many of us old fellows have been making these forms all our lives without making many substantial changes, except that Professor Henry has made improvements at the Central Office; but one of the principal improvements made by this board is the adoption of a form, or the incorporation of an idea into a comprehensive form, that was devised by an assistant observer, one of the youngest men in the service—Mr. Seeley, of Chicago. His work is worthy of commendation, because this board has really adopted his idea of having one complete, comprehensive record from which you can get any desired information regarding any day.

Mr. **Emery**. Will Professor Cox kindly tell us whether he could take the daily record into a court of justice and give the true beginning and ending of rainfall or snowfall, or the true beginning and ending of weather of any character, whether clear, partly cloudy, or cloudy, as prevailing at different times during the day?

Professor **Cox**. It has been a pleasure to me to have that record the few times I have been called into court when that record was applicable. The courts in Chicago are far behind in their work, and for that reason we seldom get into court unless the case is about three years old, but there have been a few cases in which we have appeared in court with this book, and I have felt proud to go with this little book in my hand and present that as showing the conditions. Before I have had to take three books into court. Everything is entered on that daily local record form.

Mr. **Emery**. Will Professor Cox show us on the blackboard how he would explain to a judge and jury and give them the exact time of beginning and ending of precipitation?

Professor **McAdie**. I think Mr. Emery asks an impossible question. Professor Cox can show us just exactly the data we can give the court at the present time with our present apparatus. As soon as we have apparatus that will give us the exact time of beginning and ending of rainfall, we can do it. We do not have this now, and this is one weak point in our present methods which this board had under consideration.

While I am on my feet I would like to give a word of personal explanation about this board, which otherwise, perhaps, you would not get, as the board would not allude to it. It seemed to be an impossible matter to reconcile the attitude of the stations and the requirements of the Central Office in the matter of records. When I was asked whether the thing could be done, I said no. We require two different sets of records. The demands on the stations in the last two years, especially in legal matters, have grown so considerable that we thought we needed an entirely new set of forms. I, for one, was one of the radicals who wanted this brought about. I have been familiar with the work of this board, and I have noticed throughout it all that the representative of the chief office has all the time conceded points and done everything possible to give us what we wanted on station.

Mr. Emery. If my memory serves me right, we have been reporting the beginning and ending of precipitation for many years on Form 1001.

Professor Cox. The beginning and ending of rain—in fact, every condition that may obtain during the day—appear on this form. The explanation is this, that as long as the beginning and ending of precipitation are entered on the daily record form, it was not considered necessary to duplicate that work and have them entered on the station copy of Form 1001. We have adopted a form that seemed most acceptable to all the members of the board. I think the few improvements that have been adopted have strengthened the form, although as kept by us, I believe it was very good.

Mr. Emery. How much space is given to writing up the daily record notes?

Professor Cox. You have as much space as you can desire. Instead of using the daily local record of the size of the one now in use in Chicago, we have adopted one of the size of Form 1001, which probably is half as large again. You will have more space than you have ever had before.

Professor Marvin. The board, as I understand, recommends that these record sheets from instruments be duplicated, so that the station can retain a copy. What I want to ask is, in the event that the instrument division is able to furnish them duplicate records by some means, what modification is that going to make in the preparation of this form? Will it then be necessary to duplicate or copy out this daily record on the retained copy?

I want to say, too, that I do not think Professor McAdie has quite stated the matter of recording the time of beginning and ending of rainfall. Doctor Fassig reported at the last convention an instrument for recording the time of beginning of precipitation in a different manner. The instrument has been greatly improved since that time and is probably now in form for adoption at stations, if needed.

Professor Moore. Mr. Berry, do you see anything in that method of compiling data that would affect your work?

Mr. Berry. Nothing, sir. The report we use is rendered independently, and will only be required for a part of the year hereafter.

Mr. Sullivan. In view of the fact that Professor Cox says the new station record is as near an original record as we ever had, I would like to ask him what he proposes to do with Form 1083?

Professor Cox. That is to be sent to the Central Office as heretofore. We decided not to recommend any change in that form.

Professor Cox moved the adoption of the report. Mr. Jennings seconded the motion.

Professor Abbe. The board, as far as forms are concerned, has done very well, but there are several points in which it recommends that such and such work be discontinued at the end of 1905. I think that was perhaps going farther than the board realized. There are men all over the world using our data for the study of meteorology. They will find a break, and will be writing in for the data. We can not keep up a continuous record too long. If once started, it ought to be kept up for centuries, if necessary. If the data were worth recording ten years ago, they are worth recording now.

Professor **Moore**. When we first began compiling records we were not as well informed regarding our future needs as we are now. This board provides for an amplification of the records in certain directions, and, as I followed them, I think a curtailment in others, as many of the records we have been compiling probably will not be needed. The data of which they are composed can be extracted from the records at any time that they are needed.

The report of the board, I think, will be approved, unless serious objection is made to its adoption by the convention. It will then be carefully discussed by the Central Office, and Professor Abbe will be given an opportunity to look it over and see if there is anything that interferes with his line of work. I think we have made substantial progress so far. It will be impossible for us to get any revision or improvement of the records which will meet the unqualified approval of all of us. We shall have to give and take a little for the purpose of making a general improvement.

Professor **Marvin**. There is one point I would like to ask Professor Cox about a little further, and that is his proposition to make the records of automatic instruments on local meridian time, and ask how the records are to be sent in to the Central Office on seventy-fifth meridian time? I understand it has been considered that different meridian times can be printed on the same sheet, but if the matter is investigated it will be seen that the space available on the sheet will hardly permit of more than one time without making a confused result.

Professor **Cox**. The committee did not consider it necessary to have more than one time entered, but we expected to have these instruments run on local standard time and have the sheets changed on local standard time. The equivalent of seventy-fifth meridian time might be entered on the form at various places, perhaps four or five places. I understood from some discussion or some report of yours, Professor Marvin, that you felt it was possible to enter two different times upon these sheets. We did not consider that necessary.

Professor **Marvin**. It seems to me that as the Washington Office establishes data on seventy-fifth meridian time, if the sheets come in on ninetieth meridian time there will be confusion in the Washington Office.

Professor **Moore**. In regard to that, there are 200 local offices that use these records and but one Central Office. Of course we should have these records so we can use them at both places, but if there is some inconvenience to occur it might better be at the Central Office.

Mr. **Blythe**. Referring to Professor Cox's motion that the convention adopt the report, there are a large number of us who did not fully understand the report, although it was read. If the convention votes to accept the report, the whole matter will necessarily have to go to the Central Office for final decision. For the reason that the majority of us have not had time to think the matter over, I suggest to Professor Cox that he withdraw his motion.

Professor **Moore**. We will accept your amendment in the form that the report be adopted by the convention and by the secretary transmitted to the Central Office for final action.

Upon the vote being taken, this was adopted.

Professor MOORE. I think everyone appreciates fully the very excellent work of this board. They have performed their duties well.

FORECASTING FOGS ON THE GULF COAST.

By Mr. B. BUNNEMEYER, *Providence, R. I.*

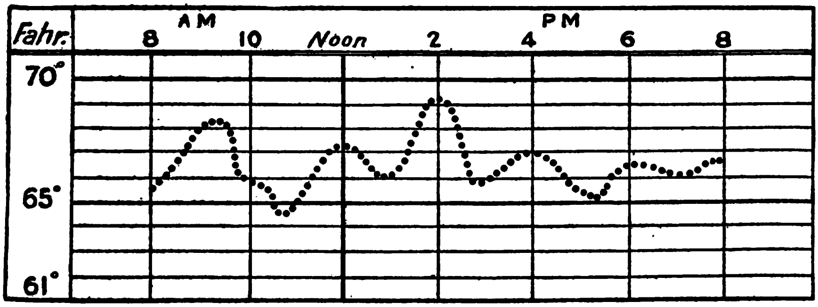
The dense fogs that prevailed on the west Florida coast from February 7 to 10, from February 27 to March 2, and again from March 20 to 26, 1904, caused so many inquiries from sea captains, pilots, stevedores, lumbermen, and the public in general that the writer was deeply impressed with the importance of giving this element some attention in the daily forecasts; and it is believed that it can be done with a fair degree of success. Even such a general phrase as "conditions favorable for the formation of fog on the coast" would enhance the value of the forecasts.

A study of the records of the Pensacola station covering the past eleven years revealed the following conditions:

1. Formations of fog during several successive days occur only during the months of December, January, February, and March. During the two months preceding and following this period they are extremely rare, and the period of duration does not exceed one day. During the summer months they are practically unknown.

2. From personal observation and inquiry it is learned that the fogs are densest over the Gulf waters near the coast, and decrease toward the interior, so that the state of the weather at the Pensacola station is not always a criterion of conditions on the Gulf coast.

3. The fogs have their maximum density during the night and their minimum during the noon hours. During the early morning and late evening detached banks of fog may be seen drifting inland; and when such drifts occur during the daytime they usually cause more or less decided fluctuations of temperature. A notable instance of such drifting occurred on March 2, 1904, when the thermograph indicated fluctuations as shown in the accompanying diagram:



4. During all fog formations the temperature is abnormally high, the departures from the daily normal being in some instances as high as +17°. The final dissipation of fog takes place with a decline in temperature to or below the normal, so that the last day of a series of foggy days may have a minus departure. A similar departure may happen at the beginning of a fog period, when there is a

decided warming up just previous to the appearance of the fog; b during its continuance the average temperature remains above t normal.

The following data, taken at random from the records of the Pens cola station, may serve to illustrate this feature of fog periods:

	Maximum.	Minimum.	Mean.	Normal.	Departure.	Remarks.
1897.						
February 18	71°	64°	68°	58°	+10	Foggy day
February 19	71°	66°	68°	58°	+10	Do.
February 20	74°	66°	70°	58°	+12	Do.
February 21	73°	68°	70°	58°	+12	Do.

It will be seen that even the minima are higher than the daily n mals, and that the range of temperature is very small.

5. The prevailing winds during fog periods are from southeast southwest, light to fresh.

6. The barometer locally gives negative results, and may be ab or below normal, and fluctuating, rising or falling, but in the g eral distribution of the pressure a depression will be found so where west or northwest of the station. In other words, formati of fog may be anticipated to the eastward or southeastward of l pressure areas.

The notes appended hereto of general and local conditions p ceding, during, and following the fogs of February and March, 19 may serve to show the type of weather most favorable for these formations on the west Florida coast:

FOG PERIOD OF FEBRUARY 7 TO 10, 1904.

February 6.

General: Low over Kansas, with barometer 29.44 at Dodge City. High o south Atlantic coast, with barometer 30.24 at Charleston.

Local: Barometer 30.06 and 0.25 lower than on preceding morning. Wi fresh to brisk southeast and south during night, and fresh south and southw during day and evening. Rain in forenoon. Mean temperature, 9° ab normal.

February 7.

General: No map issued.

Local: Barometer 30.06; no change since 8 a. m. of preceding day. Rain fresh south wind during night; light to fresh south and southwest winds dur day and evening. Dense fog during forenoon, decreasing during afternoon, increasing at night. Mean temperature, 7° above normal.

February 8.

General: Low over upper Rio Grande, with barometer 29.98 at El Paso. H over the Northwest, with barometer 30.68 at Bismarck. Fog at New Orleans

Local: Barometer, 30.05, 0.01 lower than at 8 a. m. of preceding day. Th derstorm and rain, turning to mist during night, with light southwest and w winds. Dense fog during early morning, dissipating toward 9 a. m., follo by rain. Wind, northeast and east during day and evening. Mean temp ture, 8° above normal.

February 9.

General: Low over upper Rio Grande, with barometer 29.90 at El Paso. H over Northwest, with barometer 30.74 at Bismarck. Fog at all stations on coast.

: Barometer 30.06 and 0.01 higher than at 8 a. m. of preceding day.
ast wind, veering to south in afternoon. Dense fog day and evening.
mperature, 4° above normal.

February 10.

al: Low over Louisiana, with barometer 29.98 at New Orleans. High
rthwest, with barometer 31.00 at Bismarck.
: Barometer 30.02 and 0.04 lower than at 8 a. m. of preceding day.
ith light south wind during night. Dense fog during forenoon, dimin-
Squall and rain from west at noon. Cold wave approaching. Fog
Temperature, 1° below normal.

FOG PERIOD OF FEBRUARY 27 TO MARCH 2, 1904.

February 25.

al: Low over plateau, with barometer 29.74 at Modena. High over
ake region, with barometer 30.46 at Marquette. Fog at Galveston and
leans.
: Barometer 30.11, or about stationary since 8 a. m. of preceding day.
ind, light, backing to south. Dense fog extending to tops of houses dur-
ning. Mean temperature, 3° above normal.

February 26.

al: Low over Arkansas, with barometer 29.80 at Fort Smith. High
rthwest, with barometer 30.30 at Huron. Fog at Galveston.
: Barometer 30.07 and 0.04 lower than at 8 a. m. of preceding day.
fresh south and southwest winds. No fog during day. Mean temper-
° above normal.

February 27.

al: Low over Northwest, with barometer 29.35 at Rapid City. High
rtheast, with barometer 30.54 at Portland. Fog general on Gulf coast.
: Barometer 30.16 and 0.09 higher than at 8 a. m. of preceding day.
uring night, with light to fresh southwest and west winds, backing to
uring mid forenoon. Dense fog drifting in during forenoon and evening.
emperature, 8° above normal.

February 28.

ral: No map issued.
: Barometer 30.22 and 0.06 higher than at 8 a. m. of preceding day.
ight to fresh southeast. Dense fog during morning, dissipating toward
. Dense fog late in evening. Mean temperature 8° above normal.

February 29.

ral: Low over middle Mississippi Valley, trailing southwestward, with
ter 29.70 at St. Louis. Fog at Galveston and generally at South Atlantic
.
: Barometer 30.15 and 0.07 lower than at 8 a. m. of preceding day.
ight to fresh southeast to south. Dense fog during night and morning,
hing toward noon. Mean temperature 11° above normal.

March 1.

ral: Low over North Carolina, with barometer 29.98 at Asheville and
te. High over Ohio Valley, with barometer 30.24 at Cincinnati. Fog
leston and Norfolk.
: Barometer 30.17 and 0.02 higher than at 8 a. m. of preceding day.
light to fresh south and southwest. Dense fog during forenoon and
. Mean temperature 13° above normal.

March 2.

General: Low over northwest, with barometer 29.52 at Huron. High over northeast, with barometer 30.34 at Boston. Fog at Jacksonville.

Local: Barometer 30.16 and 0.01 lower than at 8 a. m. of preceding day. Dense fog over Gulf, drifting overland during day. Light to fresh south and southwest winds. Mean temperature 11° above normal.

March 3.

General: Low over lower Lake region, with barometer 29.28 at Buffalo. High over West, with barometer 30.72 at Omaha.

Local: Barometer 30.06 and 0.10 lower than at 8 a. m. of preceding day. Cold wave and northwest storm. No fog. Mean temperature 3° above normal.

Fog Period of March 20 to 26, 1904.

March 19.

General: Low over Texas and upper Mississippi Valley, with barometer 29.62 at Amarillo and 29.64 at Davenport and Chicago. High over Northwest, with barometer 30.00 at Bismarck.

Local: Barometer 29.97 and 0.09 lower than at 8 a. m. of preceding day. Rain during night and day. Light to fresh southeast wind. Mean temperature 3° above normal.

March 20.

General: No map issued.

Local: Barometer 29.98 and 0.01 higher than at 8 a. m. of preceding day. Dense fog during early morning. Light east wind, shifting to southeast. Mean temperature 5° above normal.

March 21.

General: Low over West, with barometer 29.48 at Amarillo and Omaha. High over Northeast, with barometer 30.46 at Oswego. Fog at Mobile, Jacksonville, and stations in Georgia.

Local: Barometer 30.02 and 0.04 higher than at 8 a. m. of preceding day. Dense fog during morning, diminishing. Light to fresh southeast wind. Fog drifting in from Gulf during evening. Mean temperature 9° above normal.

March 22.

General: Low over Texas and over upper Lake region, with barometer 29.78 at Corpus Christi and 29.76 at Chicago. High over West, with barometer 30.12 at Dodge City and at Omaha. High over Northeast, with barometer 30.44 at Portland. Fog at Augusta and at Charleston.

Local: Barometer 30.09 and 0.07 higher than at 8 a. m. of preceding day. Light rain during night. Dense fog during morning, diminishing. Dense fog during evening. Light to fresh southeast wind. Mean temperature 9° above normal.

March 23.

General: Low over plateau, with barometer 29.32 at Winnemucca. High over upper Lake region, with barometer 30.34 at Chicago. Fog on coasts of Georgia and the Carolinas.

Local: Barometer 30.13 and 0.04 higher than at 8 a. m. of preceding day. Dense fog and mist during morning, diminishing. Bay clear at 3 p. m. Light southeast wind, backing to northeast. Mean temperature 9° above normal.

March 24.

General: Low over West, with barometer 29.20 at North Platte. High over Northeast, with barometer 30.58 at Oswego.

Local: Barometer 30.14 and 0.01 higher than at 8 a. m. of preceding day. Dense fog during morning, diminishing. Fresh southeast wind. Lifted fog drifting in during evening. Mean temperature 9° above normal.

March 25.

General: Low over Texas, with barometer 29.80 at Taylor. High over Northwest, with barometer 30.16 at Rapid City. Reports from Rocky Mountain and Pacific stations missing. High over Atlantic coast, with barometer 30.42 at Boston. Fog at Savannah and Atlanta.

Local: Barometer 30.18 and 0.04 higher than at 8 a. m. of preceding day. Lifted fog drifting in all day. Fresh to brisk southeast wind. Mean temperature 8° above normal.

March 26.

General: Low over west Gulf coast, with barometer 29.90 at Corpus Christi. High over Northwest, with barometer 30.58 at Rapid City and North Platte.

Local: Barometer 30.06 and 0.12 lower than at 8 a. m. of preceding day. Dense fog during morning. Light to fresh south wind. Thunderstorm, squall, and rain from northwest during evening. Mean temperature 8° above normal.

March 27.

General: No map issued.

Local: Barometer 30.09 and 0.03 higher than at 8 a. m. of preceding day. Rain and colder. Fresh to brisk northerly wind. No fog. Mean temperature 4° below normal.

Professor Bigelow asked that his paper be allowed to go over until the next morning, as he needed more time than was available. This request was granted, and Mr. Kimball's paper, "Variations in insolation and in the polarization of blue sky light," was next read.

VARIATIONS IN INSOLATION AND IN THE POLARIZATION OF BLUE SKY LIGHT DURING 1903 AND 1904.

MR. H. H. KIMBALL, *Washington, D. C.*

Shortly after the Milwaukee convention of 1901 Professor Marvin published in the Monthly Weather Review[a] a description of the Angström compensation pyrheliometer, three of which had just been purchased by the Weather Bureau for the purpose of obtaining more accurate measurements of the quantity of solar energy received at the surface of the earth than we were able to make with either type of sunshine recorder in use.

Of these pyrheliometers No. 28 was sent to Providence, R. I., where observations were made with it by Messrs. H. N. Davis and Robinson Peirce, jr., from November 5, 1901, to September 28, 1902. The instrument was then recalled, and was used by me at Asheville and Black Mountain, N. C., from November 10, 1902, to March 26, 1903. The observations obtained at Providence were published in the Monthly Weather Review for June, 1903, and those obtained at Asheville and Black Mountain in the Monthly Weather Review for July, 1903.

As there stated, I was surprised at the small values of the solar radiation obtained at Asheville and Black Mountain during January, February, and March, 1903, but particularly during March. Before my results were published, however, M. Henri Dufour, in the Comptes Rendus de l'Académie des Sciences, Paris, for March 16, 1903, announced a similar discovery with respect to measurements of solar radiation at Lausanne, Switzerland. Furthermore, he was able to state that the average radiation through a cloudless sky during January, February, and March, 1903, was from 14 to 21 per cent less than the average of these months for the years 1897 to 1902, inclusive. This decrease in solar radiation Monsieur Dufour was inclined to attribute to the presence of volcanic dust in the atmosphere.

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[a] Monthly Weather Review, October, 1901, Vol. XXIX, p. 454.

Here was an interesting phenomenon, evidently extending over a wide expanse of the earth's surface, that might be fraught with results of importance to us all; for it is recognized that the radiant energy received from the sun is the source of all life upon the earth, and if the supply of this energy were appreciably diminished from any cause we should expect both animal and vegetable life to suffer in consequence.

Furthermore, this apparent variation in the solar radiation is of especial interest to meteorologists, because, first or last, all atmospheric movements, and therefore all storms, are sustained by the solar energy. Cut off the supply of heat received from the sun and our atmosphere would become an inert mass, without relative motion. It follows that any variation in the amount of solar radiation received should have an effect upon the general circulation of the atmosphere, upon the development of cyclonic storms, and upon the weather generally.

While recognizing the inadequacy of the apparatus available for a complete solution of the problem presented, yet, in consideration of the results already obtained, upon my return to Washington from North Carolina the Chief of Bureau directed a continuation of the pyrheliometer observations. Measurements of the solar radiation have, therefore, been made at the Central Office in Washington on every working day when the sky was reasonably clear of clouds since April 17, 1903, except for the month of August, 1903, when the observer was absent on annual leave. The hours of observation have generally been 9 a. m., 12 noon, 1 p. m., and 4 p. m. The results for April, May, June, and July, 1903 and 1904, are given in Table 1.

The only previous observations with which those made between April and September, inclusive, 1903, may be compared are the Providence observations. Selecting the best day in each month for each station, a comparison indicates that the radiation during this period in 1903 was about 16 per cent less than during the corresponding period in 1902.[a] Comparing April to July, inclusive, 1903, with the same period this year, all the observations having been made at Washington and with the same instrument, it is found that 1903 again shows a deficiency, this time of about 9 per cent.

It will hardly do to compare observations made at Providence, R. I., Asheville, N. C., and Washington, D. C., during the winter months, when the differences in latitude become an important factor. But, in general, while the measurements made at Asheville in November and December, 1902, were slightly in excess of those made at Providence during the same months in 1901, from January, 1903, to March, 1904, inclusive, there was a marked deficiency in the observations at Asheville, Black Mountain, and Washington, as compared with the corresponding Providence observations, amounting in some months to as much as 30 per cent and in others to less than half this amount. As indicated above, the deficiency has been but slight since April of this year.

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[a] After returning to Washington a defect was discovered in pyrheliometer No. 28, and it was replaced by No. 34. In this paper the results obtained with No. 28 at Providence, Asheville, and Black Mountain have been divided by 0.92 before comparing them with the results obtained by No. 34 at Washington.

For comparative readings that led to the adoption of this correction, see Monthly Weather Review for July, 1903.

There are numerous other observations that show a diminution in the solar radiation received at the earth's surface during 1903. Professor Langley, in Nature for November 5, 1903, stated that there had been a marked falling off in the transmissibility of the atmosphere during 1903, as compared with 1901 and 1902, amounting to as much as 20 per cent for rays of wave length 0.50 μ, but diminishing for rays of greater wave length, and averaging about 10 per cent for all rays. He questioned whether this should not have some effect upon the climate and also upon vegetable growth, and perhaps have been the cause of the unusual coolness of the summer of 1903, reported both in America and abroad. Mr. C. G. Abbot has shown[a] that, in addition to the diminished transmissibility of the atmosphere, there was also an apparent falling off of about 10 per cent in the quantity of solar radiation received at the outer surface of the atmosphere, commonly known as the solar constant, commencing with the latter part of March, 1903. Ladislas Gorczynki[b] has published tables showing that the radiation measured by an actinometer of the Angström-Chwolson pattern at Warsaw, Russia, had fallen off 15 per cent in 1902, as compared with 1901, and 28 per cent in 1903. Dr. A. Gockel[c] states that during the course of some measurements of the ultra-violet radiation at Freiburg, Switzerland, during the winter of 1902–3, using an Elster-Geitel actinometer, he found that the energy in this part of the spectrum was very much below the normal, on some days by as much as 50 per cent. Prof. Max Wolf,[d] at Heidelberg, Baden, Germany, noted a diminished transparency of the atmosphere and smaller values for the insolation, as indicated by observations of the radiation thermometer, during the second half of the year 1902.

It will be noted that most of these writers have referred particularly to the decreased transmissibility of the atmosphere. In this connection observations upon the polarization of blue sky light, made by me with a Pickering polarimeter, in connection with the pyrheliometer observations, are of interest. Selecting again the best day in each month, we obtain the following for the polarization at a point in the vertical great circle passing through the sun and 90° from it, which is approximately the point of maximum polarization:

Percentage of polarization.

Month.	1902.	1903.	1904.
January		51.8	54.1
February		51.8	51.6
March		47.4	53.2
April			53.0
May		43.4	54.7
June		37.6	58.9
July		47.5	61.8
August			
September		54.6	
October		54.6	
November		57.6	
December	55.7	52.6	

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[a] Monthly Weather Review, December, 1903, p. 587.
[b] Comptes, Rendus, Paris, February 1, 1904, p. 255.
[c] Meteorologische Zeitschrift, July, 1903, p. 328.
[d] Vierteljahrsschrift Astronomische Gesellschaft, 1903, 38 Jahrgang, p. 117.

There was a remarkable increase in the percentage of polarization for the period March to July,[a] 1904, as compared with the same period of the preceding year. Also the percentage of polarization in June and July, 1904, was higher than at any time since observations were commenced in December, 1902.

It is not within the province of this paper to enter into a discussion of the cause of the polarization of blue sky light. Arago, Brücke, Tyndall, Lord Rayleigh, J. J. Thomson, and Pernter are some of the bright minds that have investigated this subject, and their results have been summarized for us in the Monthly Weather Review [b] by Dr. N. Ernest Dorsey.

Lord Rayleigh has shown that the scattering due to the presence of molecules of nitrogen and oxygen in the atmosphere is sufficient to account for the blue color and the polarization of sky light. The coarser particles—that is, particles whose dimensions are large as compared with the wave length of light—reflect white unpolarized light. It therefore follows that the freer the air is from dust, ice crystals, water drops, etc., the bluer it will be.

While the eye will tell us in a general way whether the sky is white or blue, it will not measure accurately the variations in the blueness from day to day. Measurements of the percentage of the polarization of the light from the sky give us a much better clue to these variations.

On the vertical great circle passing through the sun, besides the point of maximum polarization about 90° from the sun, there are four points where the light is not polarized, and they are therefore called neutral points. Two of these, one a few degrees above the antisolar point, the other about the same distance above the sun, and called, respectively, from their discoverers, the neutral points of Arago and Babinet, are quite easily observed.

It has been known for a long time that the position of these neutral points, as well as the percentage of polarization at the maximum point, varies with the atmospheric conditions. The Pickering polarimeter is not well adapted to measuring the position of the neutral points, and I have therefore seldom tried to locate them. But Professor Busch,[c] of Arnsberg, Germany, has published tables showing that while from 1886 to November, 1902, inclusive, the position of the neutral points of Arago and Babinet averaged about 19° above the antisolar point and sun, respectively, on November 19, 1902, their distances were 24° and 26°, respectively. These abnormal distances were maintained until March 22, 1903, and in the case of Babinet's point even increased up to as high as 40°.

Dr. S. Sachs,[d] in Lubeck, Germany, has published even more elaborate tables of the position of these two neutral points, confirming the observations of Professor Busch and showing that these abnormal positions were maintained at least until August, 1903.

As stated by Professor Busch, it can be demonstrated that this displacement of the neutral points from their normal positions indicates a diminution in the percentage of polarization, and is therefore in harmony with my own observations, which show a diminution in the polarization during 1903.

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[a] The excess of radiation and of the polarization of blue sky light, as compared with 1903, has been maintained up to the time of going to press, November 1, 1904.

[b] Monthly Weather Review, September, 1900, p. 382.

[c] Meteorologische Zeitschrift, July, 1903, p. 317.

[d] Meteorologische Zeitschrift, March, 1904, p. 105.

CONCLUSIONS.

There was undoubtedly a diminution in insolation during 1903, due in part at least to decreased transmissibility of the atmosphere for light and heat waves. Since Professor Langley is able to state positively that this was not due to increased absorption by aqueous vapor, we may perhaps attribute it to the presence of large quantities of volcanic dust in the upper atmosphere.

A decrease during 1903 in the value of the so-called "solar constant" is indicated by observations made at the astrophysical observatory of the Smithsonian Institution.

That a marked departure from the normal amount of solar energy received at the surface of the earth would be productive of results of vast scientific and economic value we are all probably prepared to admit. The subject is therefore worthy of the most careful consideration.

Its solution calls for a well-equipped research observatory, such as is now being constructed by the Chief of the Weather Bureau at Mount Weather, Virginia.

There will be required observations by means of balloons and kites to determine the temperature and humidity of the atmosphere at different heights, a bolometer for determining the absorption of solar radiation by the atmosphere, and an actinometer or a pyrheliometer for measuring the total quantity of solar energy reaching the earth's surface.

If it is found that there is a secular variation in the quantity of solar radiation received at the outer surface of the earth's atmosphere, we shall certainly wish to study such a variation in connection with the variations in sun spots, solar prominences, and terrestrial magnetism that are now known to exist, and it will then be in order to trace a connection between such variations and seasonal departures from normal weather conditions.

The more we study this subject the more we are impressed with the wide field covered by modern meteorological research.

TABLE 1.—*Pyrheliometer and polarimeter observations at Washington, D.*

APRIL.

1903.			
Date and time.	Q.[a]	P.[a]	Clouds.
April 17:			
11.52 a. m.	1.001	......	Few Fr. Cu.
1.29 p. m.	1.025	......	Do.
2.10 p. m.	.975	......	Do.
2.39 p. m.	.913	......	Do.
3.47 p. m.	.784	......	Do.
April 21:			
11.44 a. m.	.930	......	No clouds.
12.04 p. m.	.953	......	Do.
1.08 p. m.	.930	......	Few Ci.
1.28 p. m.	.926	......	Do.
April 28:			
10.13 a. m.	1.107	......	No clouds; light smoke lower.
10.28 a. m.	1.082	......	Do.
10.52 a. m.	1.124	......	Do.
11.30 a. m.	1.172	......	Do.
11.41 a. m.	1.132	......	Do.
12.18 p. m.	1.123	......	Do.
12.30 p. m.	1.114	......	Do.
1.44 p. m.	1.048	......	Do.
1.58 p. m.	1.107	......	Do.
2.20 p. m.	1.122	......	Do.
April 29:			
11.30 a. m.	.969	......	No clouds; light haze.
12.11 p. m.	.988	......	Do.
April 30:			
12.08 p. m.	1.050	......	8 Ci.; light haze.

1904.			
Date and time.	Q.[a]	P.[a]	Clouds.
April 4:			
9.18 a. m.	1.168	51.5	No clouds.
12.08 p. m.	1.263	53.0	Do.
1.15 p. m.	1.234	52.6	Few Ci.
4.14 p. m.	.994	52.0	No clouds.
April 5:			
9.27 a. m.	1.059	51.4	Light haze lowe
12.07 p. m.	1.102	50.2	Few Ci.; light lower.
1.14 p. m.	.944	46.7	Do.
4.09 p. m.	.562	35.8	9 Ci.; light lower.
April 11:			
9.23 a. m.	1.042	36.6	Few A. St.; fe St.
April 18:			
9.21 a. m.	.976	40.8	8 Ci.; light lower.
12.05 p. m.	1.010	35.3	8 Ci.; few Cu.; haze lower.
1.17 p. m.	1.000	25.4	8 Ci.; 1 Cu.; ligh lower.
April 19:			
9.14 a. m.	.890	38.2	3 Cu.; light lower.
12.13 p. m.	.922	24.4	6 Cu.; light lower.
April 20:			
9.18 a. m.	1.040	47.3	Few Cu.; light lower.
12.10 p. m.	1.144	47.4	Light haze few Cu.; few
1.08 p. m.	1.078	46.4	Light haze few Ci. St.
4.11 p. m.	.790	46.3	Light haze few Ci.; few
April 21:			
10.23 a. m.	1.088	44.2	Few Cu.
12.21 p. m.	1.119	44.4	Do.
1.10 p. m.	1.108	43.7	Do.
4.12 p. m.	.883	45.9	Do.
April 22:			
9.07 a. m.	1.007	47.3	Light haze low
12.06 p. m.	.987	43.3	8 fine Ci.; light lower.
1.15 p. m.	.994	42.5	Light haze.
3.11 p. m.	.748	43.2	8 fine Ci.; light lower.

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[a] NOTE.—*Q* denotes the insolation in gram-calories per minute per cm.² of normal surfa measured by the Angström pyrheliometer. *P* denotes the percentage of polarization blue sky light as measured by the Pickering polarimeter.

E 1.—*Pyrheliometer and polarimeter observations at Washington, D. C.*—Continued.

MAY.

1903.

and ne.	Q.	P.	Clouds.
:			
a. m.	1.180	48.4	No clouds.
p. m.	1.136	42.5	Do.
p. m.	1.062	40.4	Do.
p. m.	.898	38.2	Do.
:			
a. m.	.742	29.2	Light haze.
p. m.	.890	29.4	Do.
p. m.	.985	35.9	Do.
p. m.	.869	38.0	Light haze; few Cu.
:			
a. m.	.942	30.6	1 Ci.; 1 Cu. St.
	1.062	34.8	Few Ci.; few Fr. Cu.
:			
a. m.	.906	30.6	Light haze.
p. m.	.980	22.8	Light haze; 5 Cu.
p. m.	.972	22.8	Light haze; 3 Cu.
:			
a. m.	1.012	38.7	Light haze lower.
p. m.	1.074	39.1	Light haze lower; few Fr. Cu.; few Ci.
p. m.	1.099	39.8	Light haze lower; 1 Ci.
p. m.	.928	38.4	Light haze lower; 10 Ci.
:			
a. m.	.873	32.8	Light haze lower; 5 Ci.
p. m.	1.036	36.1	Light haze lower; 10 Ci.
p. m.	1.020	35.2	Do.
p. m.	.852	34.6	Do.
13:			
a. m.	.893	30.6	Light haze lower; few Cu.
4 p. m.	1.044	26.0	Light haze lower; 6 Cu.
16:			
a. m.	.488	17.0	Dense haze.
0 p. m.	.642	15.8	Dense haze; few Cu.
p. m.	.576	7.4	Dense haze; few Ci.; few Ci. Cu.; 1 Cu.
21:			
a. m.	.887	40.0	Light haze lower.
8 p. m.	.986	42.0	Light haze lower; few Ci.
p. m.	.996	42.2	Light haze; few Ci.; few Cu.
p. m.	.826	40.6	Light haze; few Cu.

1904.

Date and time.	Q.	P.	Clouds.
May 2:			
9.23 a. m.	0.928	44.8	Light haze lower.
12.21 p. m.	.991	17.5	6 Cu.; light haze lower.
1.37 p. m.	.959	13.4	Do.
4.11 p. m.	.886	47.0	Few Ci.; few Cu.; light haze lower.
May 5:			
9.18 a. m.	.989	47.8	Light haze lower.
12.06 p. m.	1.134	50.1	Do.
1.06 p. m.	1.155	48.2	Do.
4.11 p. m.	.941	50.4	Few Ci.; light haze lower.
May 6:			
9.26 a. m.	.975	48.1	1 Ci.; light haze lower.
12.07 p. m.	1.098	28.4	8 Ci; light haze lower.
3.10 p. m.	.996	48.1	5 Ci.; few Cu.; light haze lower.
May 11:			
10.40 a. m.	1.032	48.0	Few Fr. Cu.; light haze lower.
12.14 p. m.	1.063	44.4	Few Cu.; light haze lower.
1.12 p. m.	.916	36.8	4 Cu.; light haze lower.
4.06 p. m.	.724	46.3	Few Fr. Cu.; light haze.
May 12:			
9.24 a. m.	.983	49.2	Light haze lower.
12.12 p. m.	1.164	51.4	Few Ci.; light haze lower.
1.04 p. m.	1.146	51.6	Do.
4.08 p. m.	.996	53.0	Do.
May 13:			
9.33 a. m.	.964	44.8	1 Ci.; light haze.
12.07 p. m.	1.012	32.6	8 fine Ci.; light haze lower.
May 16:			
9.46 a. m.	1.197	51.4	Few Ci.; few Cu.
12.18 p. m.	1.208	46.3	3 Cu.
1.08 p. m.	1.202	49.6	2 Cu.
May 19:			
9.24 a. m.	.966	37.6	1 Cu.; hail at 11.30 a. m.
May 26:			
9.27 a. m.	.826	36.2	Few A. Cu.; light haze.
1.20 p. m.	.916	34.0	Do.
May 27:			
9.54 a. m.	1.087	38.4	1 Ci. St.; 4 Cu.
12.16 p. m.	1.126	6.6	2 Cu.
1.10 p. m.	1.023	......	4 Cu.
4.18 p. m.	.933	48.0	Few Cu.; light haze.
May 28:			
9.37 a. m.	1.183	53.4	No clouds.
12.08 p. m.	1.232	54.1	Few Cu.
1.21 p. m.	1.214	53.8	Do.
4.08 p. m.	1.022	54.7	No clouds.

TABLE 1.—*Pyrheliometer and polarimeter observations at Washington, D*
Continued.

JUNE.

1903.				1904.			
Date and time.	Q.	P.	Clouds.	Date and time.	Q.	P.	Clouds.
June 3:				June 6:			
11.51 a. m.	0.853	30.2	Light haze.	9.31 a. m.	1.139	58.9	Few Ci.; few C
1.15 p. m.	.916	32.4	Light haze; few Cu.	12.08 p. m.	1.223	54.1	Few Ci.; 1 Cu.
3.34 p. m.	.847	36.6	Light haze.	1.17 p. m.	1.224	51.4	Do.
June 4:				4.05 p. m.	......	51.1	Sun entering flow from Cu
11.52 a. m.	.815	25.2	Light haze; 1 Ci.	June 9:			
1.28 p. m.	.836	32.6	Do.	9.20 a. m.	.921	38.9	Light haze; fe 1 A. St.; few
June 9:				12.15 p. m.	.994	29.0	Light haze; fe 1 A. St.; 1 Cu.
10.08 a. m.	.422	12.8	Light haze.	1.07 p. m.	1.036	28.6	Few Ci.; 2 Cu.; haze.
June 16:				4.10 p. m.	.711	29.2	Few Ci.; 1 Cu.; haze.
11.09 a. m.	1.051	28.1	3 Cu.	June 11:			
June 18:				9.24 a. m.	1.088	50.9	2 Ci.
10.05 a. m.	1.083	35.8	1 Ci.; few Cu.	12.03 p. m.	1.120	53.0	7 Ci.
1.52 p. m.	1.026	37.6	9 Ci.; 1 Cu.	June 14:			
				9.16 a. m.	1.032	47.2	Few Cu.; light
				12.10 p. m.	1.045	41.3	1 Cu.; light haz
				1.03 p. m.	1.058	41.8	Do.
				4.06 p. m.	.739	39.6	Do.
				June 20:			
				9.24 a. m.	.953	40.6	Do.
				1.24 p. m.	1.047	40.9	Few Ci. St.; fe light haze.
				June 23:			
				9.12 a. m.	1.138	54.6	Few Ci.; few C
				12.11 p. m.	1.115	48.8	Few Cu.; light upper.
				1.17 p. m.	1.127	45.7	2 Cu. St.; light upper.
				4.04 p. m.	.778	48.0	Few Cu.; light upper.
				June 24:			
				9.18 a. m.	1.054	50.8	Few Ci.; light
				12.25 p. m.	1.114	47.4	Few Ci.; few light haze.
				1.12 p. m.	1.088	49.0	Do.
				4.17 p. m.	.913	46.7	1 Ci.; few Cu.; haze.

TABLE 1.—*Pyrheliometer and polarimeter observations at Washington, D. C.*—Continued.

JULY.

1903.				1904.			
Date and time.	Q.	P.	Clouds.	Date and time.	Q.	P.	Clouds.
July 2:				July 2:			
9.55 a. m..	0.994	42.3	Light haze; few Ci.	9.20 a. m..	1.124	50.2	1 Cu.
12.12 p. m.	1.035	43.0	Few Ci.; few Fr. Cu.	July 12:			
1.25 p. m..	1.048	42.8	Do.	9.24 a. m..	.920	40.6	1 Ci.; 2 Ci. St.; light haze.
3.30 p. m..	.904	34.9	4 Cu.				
July 7:				July 13:			
9.40 a. m..	1.113	46.6	Few Ci.	9.19 a. m..	1.196	56.0	Few Cu.
12.07 p. m.	1.143	47.5	Few Ci.; few Fr. Cu.	12.06 p. m.	1.264	61.8	Few Ci. St.; few Cu.
1.16 p. m..	1.135	46.9	Few Fr. Cu.	1.07 p. m..	1.238	57.2	Few Ci. St.
3.41 p. m..	1.002	45.0	Do.	4.06 p. m..	1.016	52.0	Do.
July 9:				July 14:			
10.08 a. m.	.942	43.5	Light haze.	9.26 a. m..	1.029	53.4	1 Ci.; light haze.
12.08 p. m.	.914	43.4	Do.	12.08 p. m.	1.168	55.7	Few Ci.; few Cu.
1.14 p. m..	.840	42.8	Light haze; few Cu.	1.17 p. m..	1.114	55.5	Few Cu.
3.43 p. m..	.729	43.4	Light haze.	4.16 p. m..	.796	46.0	8 Ci.; few Cu.
July 14:				July 16:			
9.30 a. m..	.850	41.6	Light haze; few Cu.	9.15 a. m..	.968	47.3	1 Ci.; few Cu.
12.09 p. m.	1.118	34.8	6 Cu.	12.26 p. m.	1.082	6.0	8 Cu.
1.15 p. m..	1.096	37.4	3 Cu.	July 19:			
3.43 p. m..	.968	42.2	1 Cu.	9.20 a. m..	.952	47.8	Few Ci.; light haze.
July 15:				12.11 p. m.	1.070	50.1	Few Ci.; few Cu; light haze.
9.37 a. m..	.933	31.4	5 Cu.				
12.16 p. m.	.999	25.2	3 Cu.	1.22 p. m..	1.048	48.2	Do.
1.17 p. m..	.928	13.3	3 Cu.; few Cu. St.	July 29:			
3.35 p. m..	.700	31.3	Light haze; 1 Cu.	9.29 a. m..	1.009	48.0	Few A. St.; few Cu.
July 16:				12.20 p. m.	1.092	37.3	4 Cu.
10 a. m....	1.040	45.0	Light haze lower; 1 Ci.	1.07 p. m..	1.047	35.8	5 Cu.
				4.17 p. m..	.801	36.9	4 Cu.
1.16 p. m..	1.108	19.3	1 Ci.; 4 Cu.				
3.33 p. m..	.827	23.9	9 Ci.; few Cu.				
July 17:							
9.26 a. m..	.890	42.9	Light haze.				
12.09 p. m.	1.122	6.6	Few Ci.; 3 Cu.				
1.17 p. m..	1.008	37.0	8 Ci.; 2 Cu.				
3.40 p. m..	.934	43.4	Few Ci.; 1 Cu.				

At the conclusion of the reading of Mr. Kimball's paper the convention adjourned to meet at 10 a. m. the next day.

THIRD SESSION.

Called to order at 10.10 a. m., 21st, Professor Abbe in the chair.

Calling of the roll was dispensed with.

Professor Bigelow prefaced his paper entitled "A popular account of the countercurrent theory of storms" by the following remarks:

The paper I have to read I think may fairly be called a very important paper, inasmuch as it is the result of many years of work and covers ground which is of extreme practical importance to all of us. The first word I used was "popular." That therefore brings up a subject on which I think you will pardon me if I say a word or two, namely, the relation of the man in the Bureau or the station man to the mathematician. Of course, it is often said you can not read my papers; that I write in mathematics. That is true, and I have no complaint to make; but it is one of those necessary conditions which I think you will pardon me if I say is a step in the evolution of science to which we must all submit. I came into the Bureau, I think now, thirteen years ago, and at that time I certainly knew less of the mathematics of meteorology and less of meteorology than any man sitting before me to-day. I knew a certain amount of astronomy and

I had pure mathematics. Since that time I have learned a lot of mathematics, and that apparently would imply that every man in the Bureau is able or should be able in a few years to acquire such mathematics as I present to you if he desired to do it. You will say you are busy men, and so you are. Your business lies in one direction—a useful, practical direction—and mine lies in another, also useful and practical. There should be no suspicion of envy or jealousy or anything of the sort between these two classes of men. They are the left hand and the right hand of the healthy individual. My work at present and for the past few years has been in trust to the Government, as yours is, to find out if I could what the truth is regarding some of these natural atmospheric phenomena. It is a most difficult task in itself, and our competitors are Europeans who are highly trained. They are not such practical men as you are in the field, but in the laboratory and lecture room they are powerful men. They are interested in the theory for the sake of the later practice, and one must convince them first before meteorology will come to its practical bearing in that line. Now, your observations, upon which we have to depend, are exactly as valuable to the consummation to which we are all tending as is mathematics. A beautiful illustration of exactly that principle is found in the observations on solar prominences the Italians have been making since 1871. Nothing could be more mechanical than that work; nothing in it apparently but just a continuation of these daily observations. Lately we have taken them up, and lo and behold they unfold literally more than all things else of the internal workings of the sun. You might have worked a hundred years along other lines and not have made the advance that is actually in our hands in consequence of this routine work. Now, the United States to-day possesses through your efforts an unsurpassed series of observations. I think you may therefore feel that your part in the work is just as good as mine and just as important. If I could have you before me once a day for a year, and we were to sit down as teacher and student together and go over these mathematical subjects step by step, I am quite sure that by the end of the year you would be not only interested but able to read these papers. It is only a question of effort on your part, and I do not quite see why any man should be content to sit down in the Bureau and do routine work all his life. The field is open to every man to make progress in these higher branches of science.

The hardest part that has come to me is the isolation. Here are a number of men, professors of meteorology, and still I have felt lonesome because so few men read my work; yet, as I say, it is your duty and your privilege to train yourselves into higher branches. There is no difficulty. A man may just as well say he can not read German. That is because he has not tried to get the words into his head. You can speak one language as well as another when you know it, of course. This paper is merely an effort to put into popular language which every man can understand what also has its setting in mathematical language.

A POPULAR ACCOUNT OF THE COUNTERCURRENT THEORY OF STORMS.

By Prof. FRANK H. BIGELOW, *Washington, D. C.*

1. THE LEADING METEOROLOGICAL THEORIES AND THEIR DEFECTS.

Several leading theories proposed to account for the local cyclones and anticyclones in the middle latitudes have been proved by the observations taken during the past ten years in the upper strata of the atmosphere to be erroneous. They were constructed from surface conditions, and the corresponding conditions in the higher levels were assumed to conform to certain mathematical propositions. It is usually an unsafe procedure to permit the theoretical ideas to precede a knowledge of the natural facts. Observations must govern the theory. It has been especially unfortunate in meteorology because these incorrect views have been widely taught and it is difficult to reconstruct our mental point of view. Ferrel's and Oberbeck's theories of cyclones, while differing fundamentally from each other, so that both can not be true, have one point in common, namely, they assume a warm center for the cyclone. The warm column surrounds the center and produces certain motions in the atmosphere. Yet every forecaster here knows that warm-center cyclones never occur in the United States. When the normal isobars are disturbed it is by an excess of heat, not around the center, but to the eastward of the center, between the low pressure and the preceding high pressure. The cyclone is followed by an abnormal cold area, not around the center of the anticyclone, but between the two centers of maximum and minimum pressure. This being the case, it makes everything go wrong to assume cold and warm centers as Ferrel and Oberbeck have done, and a train of untrue inferences has followed. Thus, Ferrel builds a cyclone by streams of air flowing in spirally toward the center in the lower strata, but outward in the upper strata, with the intervening reversals. In fact, however, nothing of the sort exists in the atmosphere. The outflowing components, such as the Blue Hill Observatory, Hildebrandsson, and others have published as the result of observations, are contradicted by the entire mass of Weather Bureau observations, and a recomputation of the Blue Hill nephoscope observations in 1896–97 for the upper cloud levels shows that they are not in conformity with its own earlier series. It is difficult to separate the general and the local components accurately, and the common method of reduction by the Lambert formula is inadequate to do this work so as to secure the reliable residuals of the cyclone. The cyclone is built up by an inflowing stream from the bottom to the top of it, and the observed outflow is, in fact, to be attributed to the interchange of motion from the local to the general circulation as the cyclone lifts its head into the prevailing eastward drift. There are other positive objections to the Ferrel cyclone, and that view has been finally abandoned in Europe and America.

The Oberbeck cyclone begins with a warm central column, into which the air flows horizontally from all sides and changes its direction suddenly into a vertical direction. This cyclone, besides being central, and so opposed to the facts, requires that the vertical velocity of the central column should increase with the height above the ground; that is, the air should rise faster in the upper part than in the lower part of the cyclone. This is, however, exactly the opposite of the observational results. It has been proved that the number of closed central isobars in a cyclone decreases with the height, until they finally disappear in the general isobars of the eastward drift. In winter the cyclone head is only 2 or 3 miles high, and it is always smaller in area than the base. In summer the entire cyclone reaches to greater elevations, but the structure has been shown to be the same even up to the cirrus levels. If the closed isobars that sustain the vortex motion diminish in strength with the height, that is, of course, fatal to the Oberbeck cyclone. That theory is practically the same as the Guldberg and Mohn theory, the Sprung theory, and generally the German theory. Several other difficulties exist besides these two, namely, that the local warm area is not central, and that the vertical velocity decreases with the height, and I do not think the Oberbeck analysis has any application in American meteorology. It should be noted in passing that there are many possible types of vortex motion which the atmosphere could assume under suitable conditions, and in rejecting these vortices it is merely to affirm that the conditions necessary for their existence in cyclones have not been found in our observations. It should also be remembered that the Weather Bureau has now approached its results by three sets of observations which are entirely independent of one another, but agree in producing identical conclusions. These are (1) the cloud observations for twenty years or more employed on our auxiliary charts; (2) the nephoscope and theodolite observations of the international cloud year 1896–97, and (3) the pressure maps on the 3,500-foot and the 10,000-foot planes, to which I shall further allude in this paper. These witnesses constitute testimony which it will be difficult to refute.

The theory of cyclones as eddies has had considerable support from Hann and others, but it seems to lack conformity with the leading facts. This theory depends upon an assumed difference of velocity between adjacent portions of the eastward drift, like whirls in a stream of water. It has been shown that cyclones diminish in strength from the surface upward. On the other hand, the difference of velocity increases in the upper strata, and therefore the high levels should be most favorable for the production of eddies. The cyclones die out where they should increase, according to that view. The eddy theory takes no proper account of the abnormal local temperatures. An eddy vortex should have a downward vertical component instead of the observed upward component, and the necessary velocity differences do not exist in the higher strata, as is shown by our recent nephoscope discussions for the United States and the West Indies.

There remains one more important theory of cyclones, which I have called the countercurrent theory, and the following sections of this paper will be devoted to a discussion of its principles.

2. THE OBSERVATIONS WHICH HAVE CONTRIBUTED TO THE COUNTERCURRENT THEORY.

The first new light upon the true structure of cyclones and anticyclones in the upper strata came from the vectors of motion computed by massing together the observed cloud directions in the small areas surrounding the center of action. These showed that cyclonic motion is confined to the lower strata, and that storms are shallow. The upper strata flow over the lower with but slight deflection, while the lower gyrate about moving axes. These vectors also gave the form of the stream lines, which differ greatly from the common logarithmic spirals. The next important information was derived from the nephoscope observations on clouds in the United States and the West Indies, and by resolving them into their components we obtained the general motions and the local motions, the former belonging to the undisturbed general circulation and the latter to the disturbing local circulation. These proved that the local circulation is the same in configuration from the surface upward, and that there is no reversal such as Ferrel's vortex required; also, that the type diminishes in strength with the height instead of increasing, as Oberbeck's vortex demands. These local circulations are always made up of two currents of air at different temperatures, flowing between the centers of high and low pressure, and not over them. This calls for a very different dynamic system of forces than cold and warm center areas. The third series of data consists in computing the barometric pressures at three different levels, and the set of charts beginning with December, 1902, contains the result of these reductions. These isobars confirm the results of the preceding observations and show that the cyclones diminish in intensity and disappear in the general eastward drift within a few miles of the surface. The closed isobars of the lower levels diminish in number, and wavy isobars take their place at moderate elevations. They have been inspected by several students, and no one has suggested any other mode of explaining them. A full account of their structure will be given in the annual report of the Chief of the Weather Bureau, Volume II, 1903–4. What we lack to complete the data necessary for a full discussion of the problem is a definite knowledge of the temperature distribution in the higher levels, and this will be obtained from the Mount Weather ascensions and from some other available sources. It is probable that the temperatures of the lower strata continue to hold the same relation to the isobars in the higher strata till they are gradually absorbed in the cold upper drift. The existence of warm and cold currents in the lower strata, and their dissipation or absorption in the higher strata through the machinery of the cyclonic and anticyclonic gyrations, is the problem of immediate interest to us at this time.

3. THE CAUSE OF THE COUNTERCURRENTS IN THE GENERAL CIRCULATION OF THE ATMOSPHERE.

The question arises as to the cause of these countercurrents of different temperatures in the lower strata of the atmosphere, and this brings up the subject of the general circulation of the air over an entire hemisphere. Ferrel's canal theory of the general circulation is well known, and it has been almost universally adopted as the basis of discussion, but the modern observations of the cloud motions in the higher strata have seriously discredited it. The theory assumes that the heated air of the Tropics rises to high levels and flows poleward in the upper strata, that it gradually cools and settles down to the ground around the poles, and thence returns southward along the surface. Meanwhile the rotation of the earth distorts these currents and sets up two great whirls in each hemisphere, one eastward in the middle latitudes and one westward in the Tropics. This is, of course, partly true, because the two great whirls exist, but they are of very much less energy than the pure canal theory demands. Furthermore, the cloud observations do not give us any such northward component as was expected, for at many stations the air flows directly eastward the year round, or even southward in some months, while at other stations the currents are directed southeastward almost all the time. This evidently opens a very broad subject, which can only be briefly discussed on this occasion, and, indeed, it is one which will require years of labor to investigate thoroughly. I shall therefore make a couple of remarks and then pass on to further developments.

The solar radiation enters the earth's atmosphere with short wave lengths, 0.30 μ to 2.00 μ, a portion being scattered and returning into space, another part being absorbed in the atmosphere, the balance impinging upon the surface of the earth and heating it up to a certain temperature, which is low compared with that of the sun—say, 280° and 7,500° absolute, respectively. The earth at low temperature radiates long waves instead of short waves (3.0 μ to 40.0 μ) into the atmosphere, and these long waves are not readily transmitted by it. The result is that the lower strata are the ones which are heated by the sun's radiation, although at second hand. The excess of heat above the normal amount used to maintain the average general circulation gradually works up into the higher strata by convection currents and by cyclonic motions, and together with the cooling by radiation maintains the average temperature commonly observed. We know that the diurnal variations of temperature, which are considerable at the surface where the thermometers are placed, diminish with the height and disappear within about 2 miles of the ground. There is in reality a thin skin of heated atmosphere, 2 or 3 miles thick, which is subject to excess of temperature by solar radiation, and which by the common thermal laws endeavors to set up a circulation and to reach cool air so that the heat can be interchanged with it. Let us consider the course of a heated mass lying in the Tropics, as over the West Indies. This air may seek and find cold air by two paths, the first along the ground into the United States as a warm southerly wind—and that is exactly what our weather maps show is taking place in our persistent southerly winds; or the warm air may take the long circuit upward, northward, and downward, as the canal theory requires. There is one fact, however, to be kept firmly in mind. When air moves from a locality where it has a given velocity to another place where the velocity is different there is always some interchange of inertia. But a change in momentum never takes place voluntarily in nature, and it is forced upon the object undergoing a variation of velocity. In other words, force must be applied in order to produce a gain or loss of velocity, and this nature seeks to avoid.

Thus, on the Ferrel theory, (1) the West Indian air, moving as a trade wind, rises to a place of zero or small eastward velocity, and must in so doing interchange its inertia; (2) this air in moving northward in the higher strata passes from a place of small eastward velocity to one of great velocity in the midst of the prevailing eastward drift, and that means a gain in momentum by a second interchange in ertia; (3) lastly, the air in descending to the surface in the Tem- erate Zone, passes from a high to a low velocity, and thus undergoes third interchange of inertia. This triple give-and-take of inertia in e long circuit makes it a very bad thermal path for warm air to pur- e. On the other hand, from the West Indies to the middle of the nited States, where the cyclones prevail, there is a comparatively ort path, and this is characterized by a very slight change in inertia, cause the high-pressure belt lays across the Southern States and the lateau Region, in the midst of which there is very little east and est velocity of motion. To me it seems clear that this is the general ason why the warm air of the Tropics seeks the Temperate zones in reams of air flowing in the lower strata, giving us the southerly inds which are always present on the eastern side of our cyclones. hese warm currents are irregular in their movements, since they epend in part upon the occasion or opportunity to flow as afforded y the dynamic and thermal equilibrium of the atmosphere over large egions. A similar line of argument shows us that cold northerly urrents enter the United States in the lower strata, bringing with hem the air which is cooler than the normal temperature of the sea- on. These cool and warm currents have special local conditions, ccording to their relations to the oceans and the mountains in various ortions of the earth, so that some regions are favorable and some re not suitable for bringing them together. In other words, there re certain regions, as North America, where cyclones are very umerous, and others, as Asia, where they do not frequently occur. The Rocky Mountains bend the currents in the Tropics northward, but the Himalaya Mountains form a great barrier to the flow of such surface streams from south to north. Wherever the local conditions favor the flowing together of warm and cold currents of air in the lower strata, that will be the place for cyclones to be developed.

There is another important view to keep in mind. There is a tendency for the great high-pressure belt to break up into sections, each of which is rotating, instead of holding intact directly around the earth, as the theory requires. Over the Atlantic Ocean in summer here is one such large gyrating center, and there is another over the acific Ocean. In the winter there is a tendency for these centers to ass over to the continents. At all seasons of the year there is a arked interplay between these two accumulations. The effect of ese massive gyrations of air is to make them very deep, several iles high, and to cause a persistent modification of the prevailing rth and south components in the eastward drift. Thus in the nited States east of the Rocky Mountains there is a slight northerly t to the eastward drift, while in Europe there is a distinct southerly mponent to it. Hence it will be necessary to observe these north d south components in a girdle around the earth in the middle titudes and to integrate all the vectors before we can pronounce ally regarding the resultant drift of the upper strata along the eridian taken as a whole over the entire hemisphere. My belief is at there will be found a small southerly resultant instead of the gorous northerly resultant demanded by Ferrel's theory. The tire subject is evidently of great importance to meteorology, and it ill require much careful nephoscope work in many portions of the rth before it can be settled. Returning from this consideration of the general circulation to the local circulations in middle latitudes, w may take up the countercurrent theory of cyclones and anticyclon more specifically.

4. THE LOCAL CIRCULATION IN CYCLONES AND ANTICYCLONES.

The warm current from the south and the cool current from th north flow together in middle latitudes, and by their mutual actio upon each other, and by underrunning the eastward drift which flow over them they generate the ordinary circulation found in cyclone and anticyclones. These currents may be regarded as the boiler an condenser of a thermal engine, and the laws controlling their actio are thermodynamic and hydrodynamic in a complex combinatio The heated air in cooling down is ready to do work, and the energ thus transformed is shown in the storm effects as gyrations in th lower strata. The warm air to the east of a cyclonic center seeks th cold air to the left of it, and this produces a couple of rotation. Th warm air in the eastern quadrants of a low pressure, which has under run the eastward drift above it, has a relative buoyancy, and seeks t lift itself into the higher strata. In thus raising itself from the surface the cold air tends to flow beneath it, and in this mutual actio the currents are drawn out into thin bands of different temperatures warm and cold in alternate irregular strips, which facilitate intimat mixing. The function of a cyclone is to reduce the warm and col bands to the same temperature, that of equilibrium, by intimate mixtures. The effect upon the pressure is to produce a low pressur between the warm and cold streams on one side and a high pressure on the other side of the warm stream, so that cyclones are not warm centered, but only warm on one side and cold on the opposite side. The energy of storms is, therefore, to be found in the heat transported from the Tropics and not in the heat due to the condensation of aqueous vapor into water. The condensation theory of cyclones has little truth in nature, since there occur many complete cyclones, fully developed, without precipitation. Cyclones are formed by the interaction of countercurrents of different temperature; so are tornadoes; so are hurricanes. Our recent discussion of the West Indian nephoscope observations shows that hurricanes are formed by countercurrents in the high levels, from the alto cumulus level to the cirrus level, 4 to 6 miles above the surface. The tornado is formed by countercurrents 1 or 2 miles above the surface, each overflowing a layer of stagnant air on the ground, whence the vortex tube burrows downward to the surface. Similarly the hurricane is an immense vortex tube formed several miles above the sea, which penetrates to the surface through the quiet lower strata and is carried forward by being immersed in them. Thus the last stronghold of the old condensation theory of storms has fallen down, being contradicted by numerous observations. Precipitation heat adds something to the buoyancy of the air, and to that extent it increases the energy of storms; but it is a secondary source of power, because cyclones develop in dry air as well as in moist air. Warm currents flowing from the ocean areas are usually charged with moisture, and so storms have precipitation accompanying them. In the region east of the Rocky Mountains the warm current is on the east side of the cyclone center, but west of the mountains it is on the south or west side, because in the former case the warm current flows upon the land from the Gulf of Mexico and in the latter case from the Pacific Ocean.

The gyration caused by this thermal engine produces a low pressure at the cyclone center and a high pressure at the anticyclone center as mutual and correlative effects, and in the belt of the middle latitudes there are several such centers of action more or less regularly disposed, so that the entire chain of cyclonic disturbance must be taken as girding the earth. The number of such centers varies, and that, too, in proportion to the output of solar energy, as registered in the frequency of the prominences and other visible signs on the sun. These are symptoms of the output of the invisible radiation in several forms, but they evidently will become the means of forecasting the terrestrial cyclonic effect as soon as our practical experience enables us to interpret storm results in different portions of the earth in terms of the solar action. This will demand on our part an intelligent understanding of the way in which the atmosphere as a whole responds in its complicated circulation to an impulse of solar energy. The labor of putting so much material in shape for reliable inferences between solar action and storm effects in the United States is very considerable, but I have no doubt that the problem will yield to treatment now that we have some idea as to what we should look at in our observations.

The stream-lines in cyclones are not very complex so far as the type is concerned, though they present an endless variety of modifications of the fundamental type. The two high areas embracing the low area are drawn out into two cusps, which unite over a saddle, separating a low pressure with closed isobars from a low pressure with open isobars. The streams flow into the center in spirals, and they separate at the saddle in two branches, so that the entire system is like a large open U with a true central vortex. This form is the same from the bottom to the top of the cyclone, and there is no tendency to reversal of the pressure gradients. The cyclone penetrates the moving eastward drift, and in doing so it is stripped off gradually, the outer layers being united with the drift itself, while the closed isobars at the center are diminished in number till they finally disappear in the shallow long loops of the general circulation. This process continues as long as the feeding streams flow together. The cyclone is carried forward, southeastward, eastward, or northeastward, according to the configuration of the component streams and the general drift in a given region. The cyclone and its thermal machinery pass away from the United States to the eastward, and a new cyclone is formed behind it by the same process that produced the first one. In winter there are many cyclones of much power, because there is great contrast in the temperature of the parent streams. In summer the cyclones are few and feeble, because the temperature contrast has disappeared. As the summer approaches the streams flow higher above the ground, and the cyclone is more vigorous in the strata 2 or 3 miles above the surface than at the ground, because it must reach higher in order to find the cold air necessary for bringing its heat down to an equilibrium. Thus the problem of the temperature equilibrium is before us.

5. THE EQUILIBRIUM OF TEMPERATURE.

The primary use of cyclones in the economy of the earth's atmo phere is to constitute a machine for reducing to a mean temperatu the extremes produced by extra heating in the Tropics and by und cooling in the polar zones. Masses of air at different temperatur do not readily combine, and they will not do so unless force employed. Hence, in cooling the warm current and in warming t cold current, which feeds a cyclone, energy is set free in the form dynamic motions, which quickly become vortex whirls of small a large sizes. These whirls interpenetrate, curl about in all sor of curves, and are accompanied by a rapid interchange of inerti wherever a quiet mass is taken up and set in motion, or wherever moving mass is reduced to rest. I am not able at this time to sta what the relations are between heat and motion in cyclones a anticyclones. The entire temperature problem is, however, und investigation, and we are devoting our energies to a reduction of o temperature records since 1873, to render them homogeneous. T problem of temperature is more difficult than that of pressure for t United States, as can easily be shown, and it will take us some ti longer to secure accurate temperature monthly normals and annu variations. Meanwhile we hope to procure numerous measures temperature at higher levels, which, in connection with similar da taken in other places, will enable us to solve the thermodynam problem of the general and local circulation in the United Stat The balloon and kite plant at Mount Weather will be organized f this purpose.

6. THE INTERCHANGE OF INERTIA.

An allied problem which can not be reported upon at present the interchange of inertia in the circulation of the atmosphere. Fe rel's theory of the general circulation leads to an impossible eastwa drift in middle latitudes and an excessive westward drift in t Tropics. I have suggested a new method of approaching the pro lem in my paper in the Monthly Weather Review for January, 190 No. III, "The problem of the general circulation of the atmosphe of the earth." Some powerful forces are in operation to slow dow the general circulation to its observed moderate speed, and ther must be a drag brake constantly acting upon it. This is to be found I believe, in the mechanism which accompanies the penetration o the warm air from the Tropics into the upper strata, through th cyclones of middle latitudes, as explained previously. The rotatin cyclone raises its head into the higher strata and is there graduall stripped of its masses, which are absorbed in the eastward drift. But in this mechanical process the air of the cyclone has one velocity and that of the general circulation another velocity, and these two tend to an equality by a mutual interchange of their momenta, so that the eastward drift is retarded while the cyclone is carried towar the east. The hydrodynamical problems involved in this question are serious and complicated, but much has already been done leading to their solution. We have found some reliable vectors of motion up to the height of 6 miles for the United States and the West Indies, winter and summer, and these must be accounted for in the solution. They differ so much from those resulting from Ferrel's and Oberbeck's equations that I believe that it is useless to proceed further along the old lines. There is doubt in my mind whether it will ever be possible to secure a general solution, except in a merely approximate way, serving as a suggestion to the proper line of thought. The air mass in circulation is so far localized over given regions up to great heights that these must be the subject of special local investigations. Thus the United States, West Indies, and Atlantic Ocean form one such large local field. They can not be separated from the entire circulation, but each field must be fully discussed and organized before it can be fitted into the whole dynamic structure. The two transformations mentioned, the interchange of heat and the interchange of inertia, are the two keys to the problem, which must be traced from step to step, from minor whirls to cyclones and anticyclones, to large circulating regions, and finally to the entire terrestrial atmosphere. We believe that similar conditions prevail in the sun and that the solution of one problem involves that of the other. Meteorology in this sense, in so far as it embraces the circulation and radiation of atmospheres, is evidently the primary subject, to which common astrophysics, cosmical radiation, and terrestrial magnetism and electricity contribute important pieces of information. The circulation of atmospheres is the first problem, and these solar and terrestrial effects are secondary, being dependent upon them. Meteorology should rise to its noble future in the advancement of science and firmly reject the assignment given to it by those scientists who assert that it is not yet worthy of a place among the exact sciences.

7. THE RELATION OF THE THEORY TO FORECASTS.

I have reached the limit of my time already and should be obliged to say much more if I were to state all I have in mind regarding the subject of local forecasts. A large part of my report on the circulation of the atmosphere (Annual Report of the Chief of the Weather Bureau, 1903-4) is devoted to this subject, which is copiously illustrated in various ways, and that must take the place of a fuller statement here. Forecasting is a practical matter, after all, and its value will be known only by really trying it under the usual conditions. The Chief of the Weather Bureau has therefore arranged for placing the necessary code word on the wires, beginning with December, 1904, and it will be proper to postpone further discussion of the matter till we have had time to report upon the actual record that will then be made. Meanwhile I will only remark that I have found my own judgment of the course to be pursued by cyclones and anticyclones greatly steadied and instructed by the simultaneous use of isobars on the sea-level plane, the 3,500-foot plane, and the 10,000-foot plane. I have obtained a promising improvement in precipitation forecasts for the entire United States over those officially made. It may be that one can learn to do better with practice, though I prefer to make no claims on this point beyond stating that fact. There is no doubt that the additional knowledge given by the upper maps greatly extends the possibilities of the forecast work beyond that of any of the auxiliary charts now in use. When daily isotherms on the upper planes are added to the isobars we may hope for still further progress in short-range forecasting. When the necessary material is in hand we hope to be able to do something valuable in general and seasonal forecasting from one year to another over the broad areas of the earth.

DISCUSSION.

Professor McAdie. Professor Bigelow spoke of the sense of isolation, and was kind enough to say we could all be Bigelows if we would try. He must not feel that way—that we on station are not trying to follow him. I think many of us are doing our level best to do so. I think Professor Bigelow would be surprised to know that on some stations we are reading him very closely. I speak for one station where we have read every word that he has written. We have not proved all his formulas; we have not had the time nor the men with mathematical ability, but we have done our very best to follow him. If he were to come to the San Francisco office he would find his book on Barometry more thumbed than any other book in the bookcase. In fact, we were able to pick up an error in the data for the station and send it back to the Washington Office. It was not a typographical error, but one of computation. That, of course, was nuts to the boys on the station, for when they make an error of a thousandth of an inch they are promptly held up. What seems to me most wonderful in Professor Bigelow's writings is his suggestiveness. We can hardly keep up with that. There is a good deal of repetition in his works, but that does not count, because he drives his points home. Then, in our practical work we are trying to put to practical use some of the leads which he has opened up for us, as for example, in so simple a matter as protecting raisins. We have tried to do that in connection with the system of winds on the Pacific coast, but you must not forget, Professor Bigelow, that we have been brought up in a hard school; we want our checks certified, not that we doubt any man's credit, but experience has taught us it is necessary. So we go on with our work, doing the best we can.

You use an expression about wishing that some of us might come to you as students. I would never have mentioned it, but it has been my secret wish for several years that I could sit at the feet of Professor Bigelow and be his student, but I feel that we owe something of a direct return to the people who support us and we must give them back something without delay. These are the practical daily-bread problems which must be considered. If I could have my choice I would come and sit at the feet of Professor Bigelow. I am afraid he would find me a hard-headed student, who would object to some of his points, but nevertheless I would be glad to be a student of his.

Mr. Salisbury. I also, as a representative of a portion of the Pacific coast, have endeavored to follow Professor Bigelow's demonstrations, and of course have done it very imperfectly on account of not having the necessary mathematical education, but I have endeavored, in such popular expositions as he has made, to adapt his theory to our Pacific-coast conditions, and I confess my inability, although his theory appears so reasonable and plausible for the continental portions of the United States, because I see many points in which it seems to me that the theory does not conform to our conditions. That of course may be ignorance on my part, and I would be glad if Professor Bigelow would devote a little more attention to those storms which appear on the Pacific coast, coming apparently from nowhere, and originating, in my mind, far distant upon the Pacific Ocean rather than upon the land, and explain why the wind currents are contrary in summer to what his theory would call for. Now, during the summer there appears over California a low-barometer area which always brings us warm weather—not with warm, southerly winds, as one would think, but with northerly winds. I am referring here to conditions which come to Washington and Oregon. Our warm waves which come from the south do not come with southerly winds, but with northerly winds, which is contrary to the circulation, as he showed us, upon the Pacific coast. Another objection is, Where do these counter currents come from over the Pacific Ocean, where the storms must have originated, because they surely come from the west and do not form over the land? I would like to believe his theory; I do believe in it, but it seems to me there is much that is unexplained by his theory in the meteorology of the Pacific coast and the Northwest.

Mr. MITCHELL. I wish to second the observations of Mr. McAdie in regard to Professor Bigelow. I have read his work, as far as possible without a knowledge of many of the formulas that one necessarily forgets in the course of time, but I have read all his work with a great deal of pleasure and profit. While he may be alone, he occupies the position of the fox, and the hounds are right after him.

Professor ABBE. I suppose it is fair to say that the atmosphere is so full of whirls and motions that one man's work may be concerned with one part of the atmosphere and another man's with another, so there is plenty of work before us for all of us. The fact that we are all reading Professor Bigelow's papers almost negatives what the Chief has said, that we are publishing too much. The better we write, the more we can afford to publish. Like all the rest of the world we want the best we can get and plenty of it. Professor Bigelow's thermodynamic and hydrodynamic formulas must contain the laws of storms and weather, and his work must be studied at Mount Weather until it is thoroughly understood.

A POSSIBLE METHOD FOR DETERMINING THE DIRECTION AND VELOCITY OF STORM MOVEMENT.

By Mr. EDWARD H. BOWIE, *Saint Louis, Mo.*

It is generally conceded that nearly all failures in weather forecasting are due to an imperfect knowledge of the forces which control the movements of cyclonic areas. That the operation of these forces frequently results in unexpected movements is the experience of every forecaster. It is therefore patent that in order to improve the accuracy of forecasts some method must be devised whereby the future direction and velocity of movement of the cyclonic areas may be more accurately outlined than they are at present. The practical forecaster fully understands this need when, after exercising all the ingenuity and ability gained from many years of study and experience, he frequently finds that his conclusions have been incorrect and his predictions in error, by reason of some unseen condition—unseen because of an imperfect conception of the data from which the forecast was ventured, or because of a sudden change of conditions occurring after the time of taking the observations given him for consideration.

Meteorologists recognized this fact long ago, and much time and labor have been bestowed upon the solution of this problem; thus far with practically few productive results. The study of storm movements has, however, resulted in the formulation of a number of rules or laws that are of more or less aid to the forecaster. The statement that storms follow the lines of least resistance is certainly worth considering, as it is in accord with all known laws governing the operation of forces, and it might have become the key of the solution of this problem long ago had not its formulator contented himself with a mere axiomatic statement to that effect. Unfortunately for the science of meteorology we are left to conjecture whether these lines of least resistance lead toward the region of relatively low barometric pressure, as some contend, the region of most rapid condensation, the district showing the greatest fall in pressure in any stated interval of time, or along and parallel to the isothermal lines.

Each of the above propositions has its adherents, and twenty-five years of study and discussion have apparently added little to the known facts regarding the movement of storms, except as deduced by the law of averages.

Every person who attempts to forecast the weather sooner or later becomes painfully aware of the limitations of his knowledge with respect to the movement of storms, and it is with the hope of being able to shed some additional light on the cause for the so-called "erratic storm movements" that the result of three years' study of this subject is given to this convention.

Reviewing the works of a number of writers on meteorology, several statements are found that throw more or less light on the subject of the predetermination of a storm's direction and velocity of movement. Abercromby, in his Principles of Forecasting, plainly states his belief that the types of cyclones visiting the British Isles have their direction and velocity of movement dependent on the geographical distribution of barometric pressure, or the location of the adjacent areas of high pressure. He states that the most casual inspection of a number of charts under consideration showed that when a cyclone is formed its path is controlled far more by the pressure in the front of it than by any other force, but at the time that he published his work Abercromby had not the means of studying the effects of the pressure over the North Atlantic in the rear of these storms. In this connection, however, he remarks that there is a great field of research open for study of the relation of the pressure to the leeward of an advancing cyclone to its future path. He concludes his observations by stating his belief to be that cyclones follow the lines of least resistance, a conclusion at which the Rev. W. Clement Ley and others also arrive. The Reverend Ley, in his work entitled "The Study and Forecast of Weather," states that with one important class of exceptions the cyclonic systems commonly advance in such a direction as to keep the anticyclone on the right of their course. The exceptional cases referred to are those in which, in the region of the British Isles, a cyclone lies to the immediate south of an anticyclone. Ley believed that the condensation of moisture is most active in the district which occupies the front of the cyclone or region toward which the cyclone advances, and assigned this as the real cause for the advance of the cyclone by a constant reproduction of itself in that quarter.

Sir John Eliot announced that a cyclonic vortex when generated in the middle of the Bay of Bengal always traveled toward that part of the coast where the wind velocity for the time being was least, as compared with the average velocity for the same place and time of year. According to Eliot this law was verified by almost all the cyclonic disturbances that had occurred in the bay since the chain of meteorological stations was established around it. This law is practically a duplication of that one which is to the effect that storms move toward the region of relatively low barometric pressure, because an absence of wind velocity of importance implies a region of low barometric gradient.

In the Law of Storms, by Rosser, he remarks that the progressive motion of cyclonic systems depends mostly upon the general motions of the atmosphere, but also upon the tendency of the cyclones to press toward the poles, and that the progressive velocities and directions are very different in certain cases. This theory was also adhered to by Professor Ferrel. It follows from this that there must be other modifying influences, and Rosser concludes that perhaps among these the principal ones are the distribution of aqueous vapor and the positions of the general isothermal lines.

Professor Abbe, in his Preparatory Studies for Deductive Methods in Storm and Weather Predictions, remarks as follows:

> The statistics of American storms, as given by Loomis, and those of Indian storms, as given by Eliot, unite in a confirmation of the views herein expressed, that of all the causes that contribute to the motion of the storm, namely, (1) the unbalanced northward pressure attending a low, as deduced by Ferrel; (2) the drift of the general current of the atmosphere that carries the air and the storm along together; (3) the insolation that stimulates uprising currents on the sunny side; (4) the orography that promotes cloud growth and rain on the windward side of mountains and coasts; (5) oceans and lakes that promote evaporation and moisture; (6) the geographical distribution of areas of high pressure; (7) the precipitation of rain that leaves heat free in the cloud. Of all these, the last, when it occurs, becomes the leading factor in determining the progress of the whole disturbance.
>
> It has been customary—

Says Professor Abbe in this report—

> to speak of the areas of high pressure as pushing the low areas or as opposing their progress; but this is evidently only an apparent result of the complex phenomenon going on, as each one virtually feeds the other with moist air and dry air, respectively.

In the Monthly Weather Review, of November, 1896, Professor Abbe remarks that the movements of the areas of low pressure across North America are elucidated by studying the upper isobars of the Northern Hemisphere, believing that the whole upper circulation of winds and clouds and the general movement of areas of low and areas of high pressure are related to this distribution of pressure in the upper layers of the air.

On the question of the effect of the areas of high pressure in determining a cyclone's path, Professor Bigelow states it to be his opinion that the cyclone is not only dependent on the areas of high pressure for its direction of movement, but largely for its origin as well. It is plainly evident that Professor Garriott is a firm believer in the theory that areas of high pressure control to a large extent the movement of cyclones, and in an article on "Tropical storms of the Gulf of Mexico and the Atlantic Ocean in September," published in the Monthly Weather Review of May, 1895, he lays great stress on the modification of storm movement by areas of high pressure, and gives therein practical rules that are of the greatest assistance in forecasting for determining the probable longitude of recurving of tropical storms.

In the "Report of international cloud observations," Professor Bigelow demonstrates conclusively from cloud observations that the air at the cirrus level in the middle latitudes of North America has an almost due east movement, and he contends that the cyclonic and anticyclonic movements are in the main the result of this eastward drift, as modified by the north-south underlying countercurrents. When this eastward drift as modified by the underlying countercurrents is considered, the reason for the average storm tracks across the American Continent is readily understood; and it logically follows that under normal conditions these average storm tracks are in reality the lines of least resistance which the storms follow. But under certain conditions these lines are departed from by the cyclones in their eastward movement, and it is to the consideration of these abnormal conditions that much time and thought must be given to elucidate the reason for the so-called erratic storm movements, as the wide departures from these lines of least resistance, or average storm tracks, are the occasion for nearly all radical failures in weather forecasting.

It is a matter of common observation that in the middle latitudes a storm found south of an area of high pressure pursues a course that lies to the right of the track that storms of that particular locality usually travel, and the converse is true when an area of high pressure is found south or southeast of a storm center; moreover, when an area of high pressure covers the region toward which a storm under normal conditions moves its progressive motion is slow, but when an area of high pressure develops in the rear of a storm its movement is accelerated.

The influence of the area of high pressure in deflecting storms from their normal or usual course is clearly set forth by Professor Garriott in the paper on "Tropical storms in September," hereinbefore referred to. In this paper Professor Garriott divided the tropical storms of September into three classes, namely: First, those that recurved east of the sixty-fifth meridian; second, those that recurved between the sixty-fifth and ninetieth meridians; and, third, those that passed west of the ninetieth meridian or reached the United States without a recurve. Of the first class of storms, all of which first appeared east of the fiftieth meridian or north of the twentieth parallel, Professor Garriott observes that only two appeared far enough to the south to render their advance over or near the West Indies a probability, and that in every instance the westward movement of the cyclones which recurved east of the sixty-fifth meridian was apparently prevented by anticyclonic areas which moved eastward over the Southern States and obstructed the westward advance and forced a recurve to the northward. He states that the recurve of storms of the second class, i. e., those that recurved between the sixty-fifth and ninetieth meridians, was apparently due to the obstruction offered to a westward course by anticyclonic areas which had advanced or had been drawn from the continent over the West Gulf and Southwestern States. A large proportion of the third class of storms advanced westward from the eastern West Indies. On their arrival in about longitude west 80°, the average longitude in which September tropical storms recurve, the pressure over the West Gulf began to decrease and rain set in, while the interior eastern districts of the United States were occupied by an extensive area of high pressure. As storms prefer to follow the path of least resistance, the centers moved toward the region of decreasing pressure and avoided the high and increasing pressure to the northward. When the pressure continued high over the eastern districts of the United States the storms were unable to recurve, and were penned in over Mexico or the Southwestern States. In such instances, Professor Garriott states, the cyclones developed great violence before disappearing. Similarly, cyclones of this class that advanced northwestwardly toward the middle or south Atlantic coasts of the United States were apparently prevented from recurving by high pressure over the ocean to the northward and northeastward, and, being forced upon the coast, developed destructive energy.

From the foregoing it appears that the effect of distribution of pressure in determining a storm's path is recognized in practical forecasting. It follows that forecasters are more or less unanimous in the opinion that an explanation of erratic storm movements is to be found in the unequal pressure distribution surrounding a storm's center. Assuming erratic storm movement to be due to unequal pressure distribution, it is manifest that the direction and velocity of storm movement could be determined were it possible to obtain correct values that would represent the pressure exerted upon a storm from all directions and the eastward drift of air at high levels that carries the storm with it. Working on this theory, effort has been directed toward obtaining a value that would represent the twenty-four hour eastward drift from any given locality. To find this value it has been necessary, first, to determine the resultant of the pressure from all directions toward the storm center. To represent this pressure from all directions, lines radiating from the storm center to the north, northeast, east, southeast, etc., have been given, after considerable experimental work, a length of 1 centimeter for each tenth of an inch increase in barometric pressure along these lines, working with a map the scale of which is 160 miles to an inch, or that of the Washington weather map. The resultant of such lines, or forces, acting toward the storm center, which may be found by the rules governing the polygon of velocities, will show the direction toward which the unequal pressure is forcing the storm.

If the pressure of the air from all directions toward the storm center be a factor in determining the direction and velocity of movement of a storm, it is obvious that this resultant, representing the value of and direction toward which the unequal pressure forces the storm, becomes one of the components that determine the storm's path.

As the twenty-four hour movement of any given storm is the measure of the forces that determine that movement, it follows that by using this resultant of pressure toward the storm center as one of the components which cause the storm to move along its path it is possible to find the other component of motion by resolving a force representing a storm's twenty-four hour movement into its two components.

One of these components representing the pressure effect being known, the other component, representing the eastward drift, may be found by the rules governing the parallelogram of forces. If there be a basis for this theory, it must necessarily be that the second component, representing the eastward drift, should have approximately the same direction and value for two or more storms in the same locality for any given month of the year, provided the appropriate value is given the pressure acting toward the storm center from all directions.

This component has been found for a large number of storms, whose values when charted show an agreement that appears to be more than accidental or merely coincident.

Having found the component representing the twenty-four hour eastward drift, which component is apparently fairly constant in value for any particular locality from year to year for a given month, and the resultant of the pressure exerted on the storm center from all directions, the value of which is a variable quantity, it is patent that the direction and amount of movement of a storm is the resultant of these two forces. Thus, for instance, a December storm charted in Colorado, subject to a pressure that tends to force it southward 400 miles in twenty-four hours, is during the same period being carried eastward 450 miles by the flow of the upper currents. It is evident that the storm's actual path will lie between the two lines representing the eastward drift and the pressure that forces the storm to the south, the resulting movement being almost due southeast and a distance of approximately 600 miles.

From a study of storm movement along the lines outlined above it is apparent that the rate and direction of movement of a storm in relation to its normal movement is governed by this variable component, representing the deflective force, or the resultant of the pressure exerted on the storm from all directions; hence it follows that when this deflective force is toward the left (when facing the direction of normal progression) the storm will move to that side of the normal direction of advance, and when toward the right the converse will be true. When this deflective force is acting in conjunction with the eastward drift, the storm's rate of movement will be accelerated and when in opposition the storm's progress will be retarded. It appears that in nearly all instances the storm increases in intensity when this component, representing the pressure of the air toward the storm center, is acting to the left of the normal direction of advance, but when toward the right the storm as a rule will decrease in intensity.

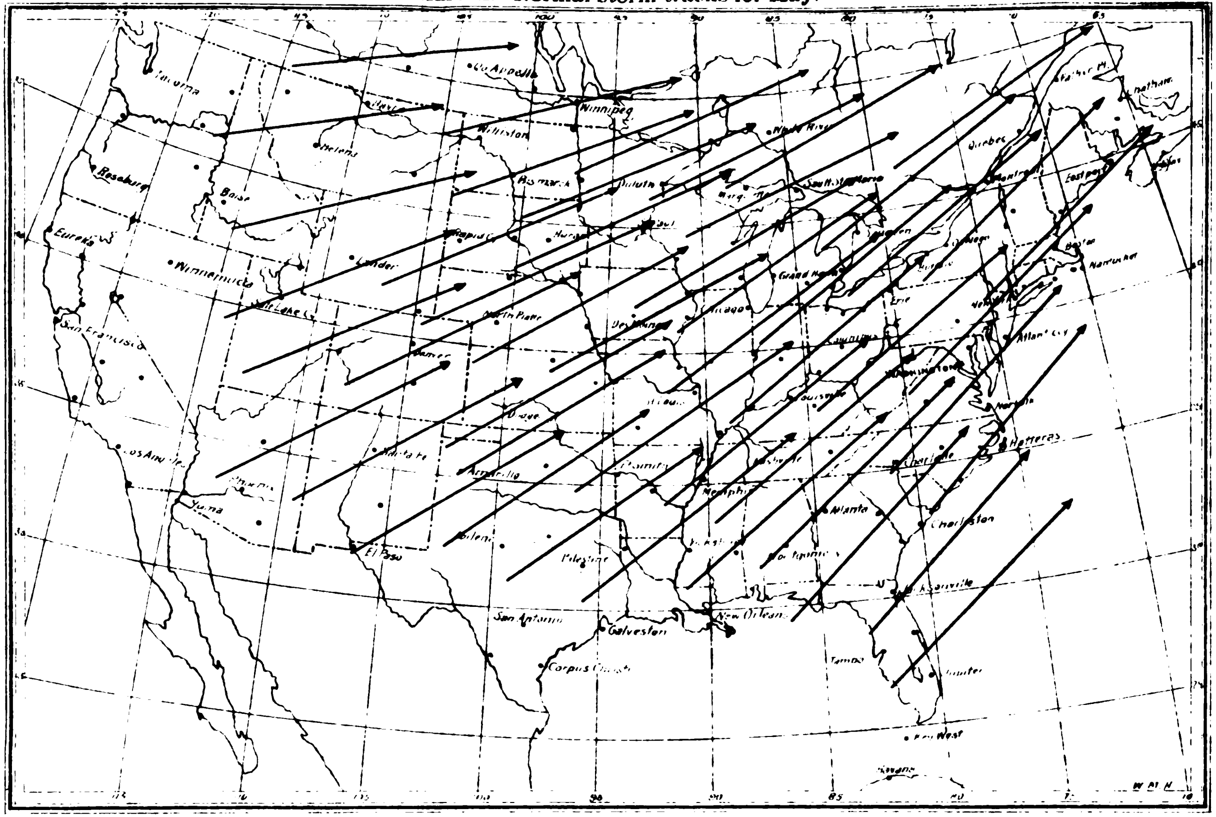
Naturally exceptions are to be found in applying the method outlined above, but in practically all instances the exceptions have been the result of an unforeseen increase or decrease in the pressure toward the storm center from some one of the several directions, which, in addition to offering an explanation of the exceptions, tends to prove the correctness of the principle. Of course the application of the method is limited when the storm center is near a region from which no pressure observations are available—as, for instance, the storms that move along the Canadian border. In cases where there are a number of ill-defined storm centers it is not always possible to determine which center will become the primary one and which centers will be dissipated, and therefore there is more or less doubt hether the deductions will be borne out by subsequent events. In arly all instances involving exceptions the error in predetermining e movement of the center is apparently due to inability to deterine the exact values that should be used to represent the pressure ward the storm center from the several directions.

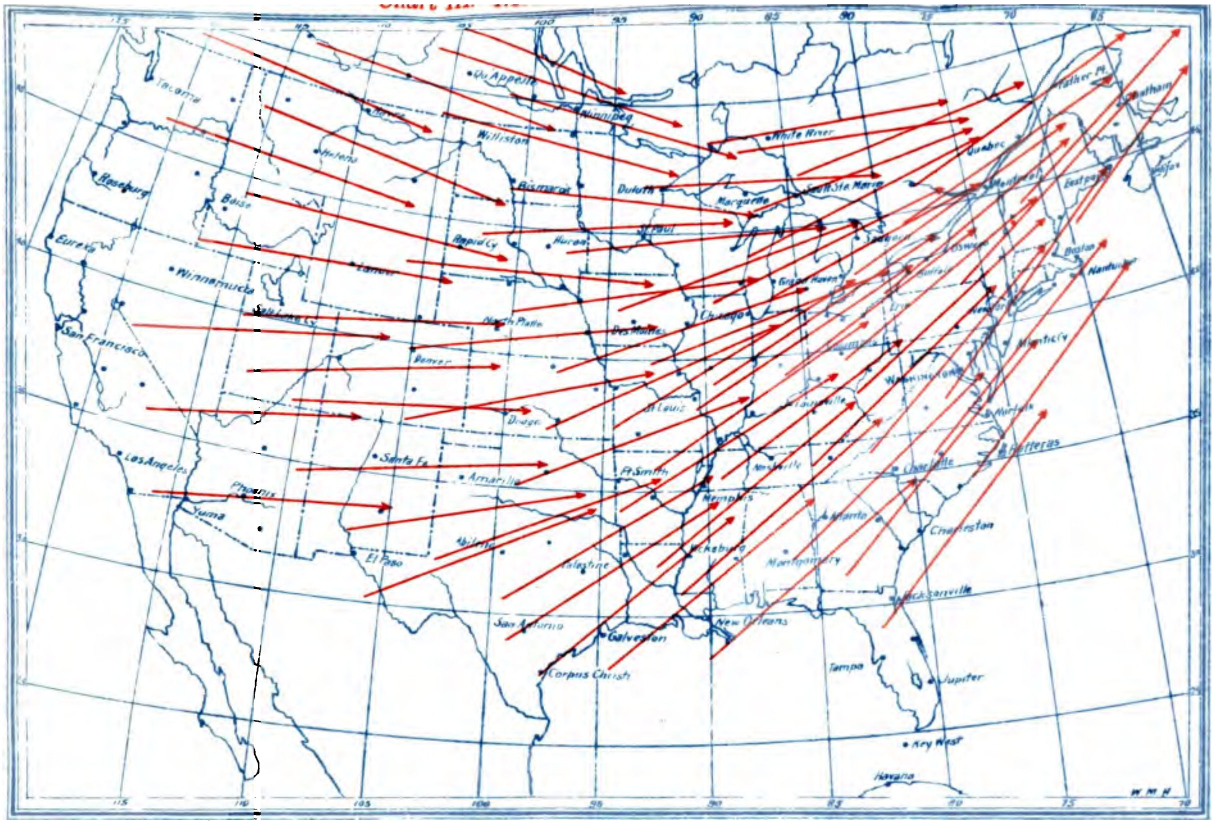
The values determined by the methods used in the research along e lines indicated above are necessarily approximations only, and, erefore, tentative; but it is believed that by refined methods of comitation values representing the pressure exerted on the storm center well as the normal direction and velocity of the eastward drift can found that will show the exact conditions, and thus lead to a higher gree of accuracy in charting the direction and movement of storms. The accompanying charts illustrate the method followed in develing the "normal storm tracks" and the application of the system practical forecasting to determine the direction and rate of moveent of storm centers during twenty-four hour periods.

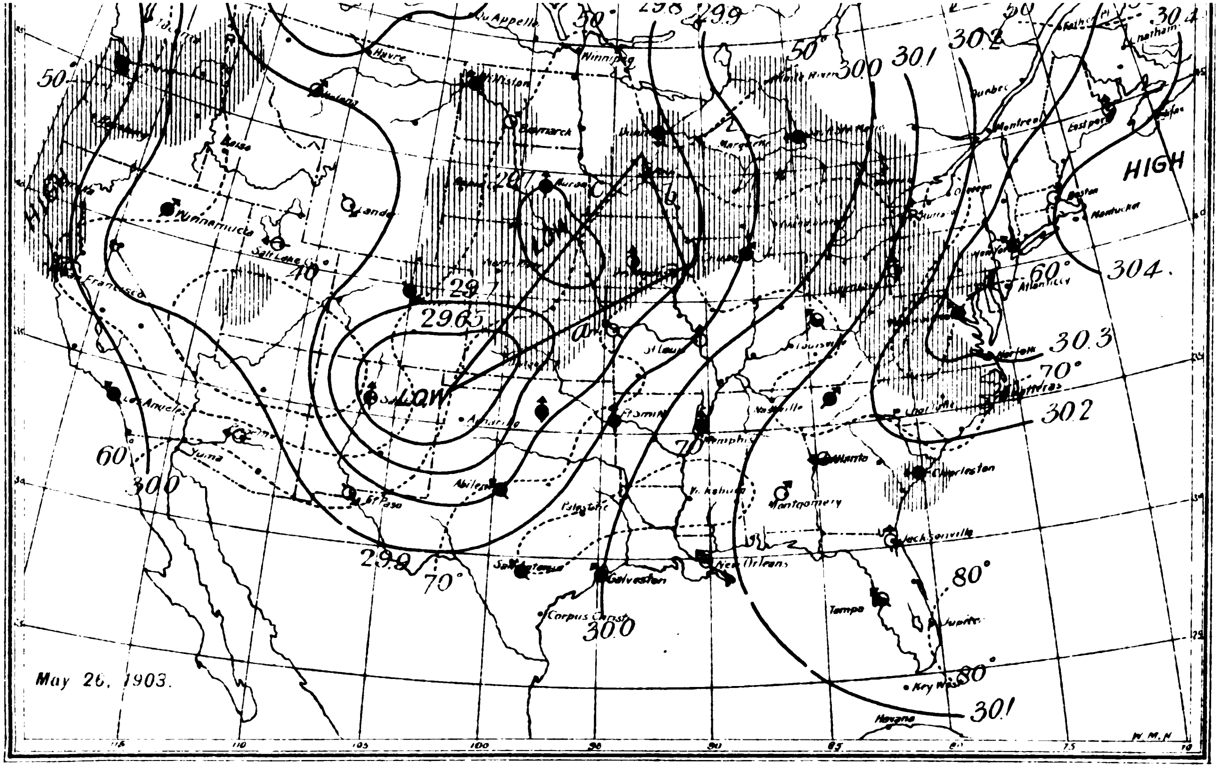
Chart I shows the method followed to determine the correct value r each tenth of an inch increase in the barometric readings along es radiating from the storm center to the north, northeast, east, ., to represent the influence of the pressure exerted on the storm nter from the several directions; it also illustrates the method folwed in developing the "normal storm tracks" for a given locality. this figure, drawn to the scale of the Washington weather map, the ctor X represents the direction and movement in twenty-four hours the storm that was centered near Amarillo, Tex., 8 a. m., May 26, 03. The vector X_1 is the resultant of the pressure acting from the rth, northeast, east, etc., in the direction indicated, and was deterined from an increase in pressure from the storm center at 8 a. m., ay 26, as follows: To the north, 0.10 inch; northeast, 0.00; east, 30; southeast, 0.30; south, 0.30; southwest, 0.30; west, 0.30, and rthwest, 0.20, each tenth of an inch being given a value of 1 centieter. The vector Y represents the twenty-four hour movement of e storm that was centered over Amarillo, Tex., at 8 a. m., May 28, 03. The vector Y_1 is the resultant of the pressure exerted on the orm center, determined as above from an increase in pressure from e storm center toward the several directions, as follows: To the rth, 0.30 inch; northeast, 0.20; east, 0.60; southeast, 0.30; south, 10; southwest, 0.10; west, 0.10, and northwest, 0.40.

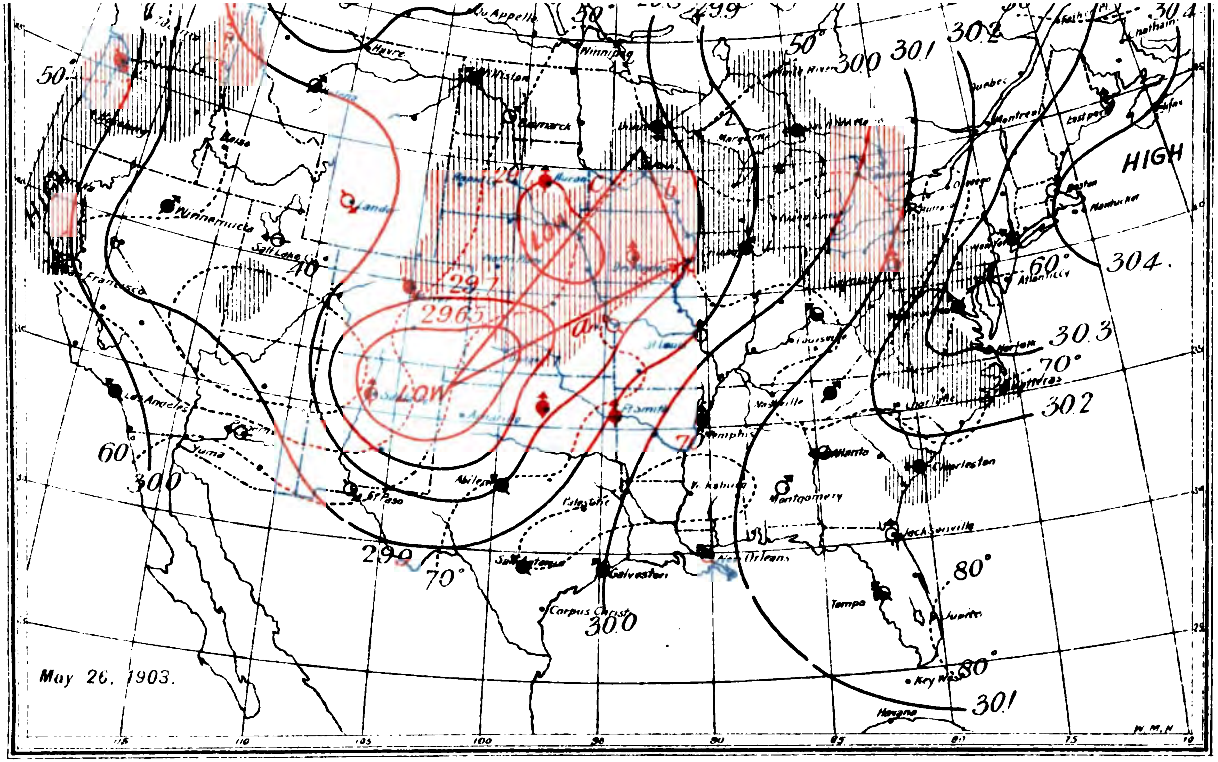
The vector X being the resultant of the forces that propelled the orm in the direction and to the point indicated in twenty-four hours, is possible to eliminate the pressure influence (if it be given an ppropriate value) by resolving the vector representing the track of he storm into its two components, one of which, X_1, being the resultnt of the pressure exerted on the storm, the other, X_2, will represent he twenty-four hour value that should be given the general circuation of the atmosphere that carried the storm with it. Similarly, Y_2 represents the twenty-four hour value that should be given the eneral circulation that carried the storm of May 28 with it. It will e observed that X_2 and Y_2, representing the twenty-four hour values f the general circulation on the two dates, are of equal length and ary not more than 3° 30′ in direction, from which it may be assumed hat the general circulation of the atmosphere in May that carries the storms of the region of New Mexico and northwest Texas with it may be represented by a mean of a number of vectors determined as

Chart II.—Normal storm tracks for May.

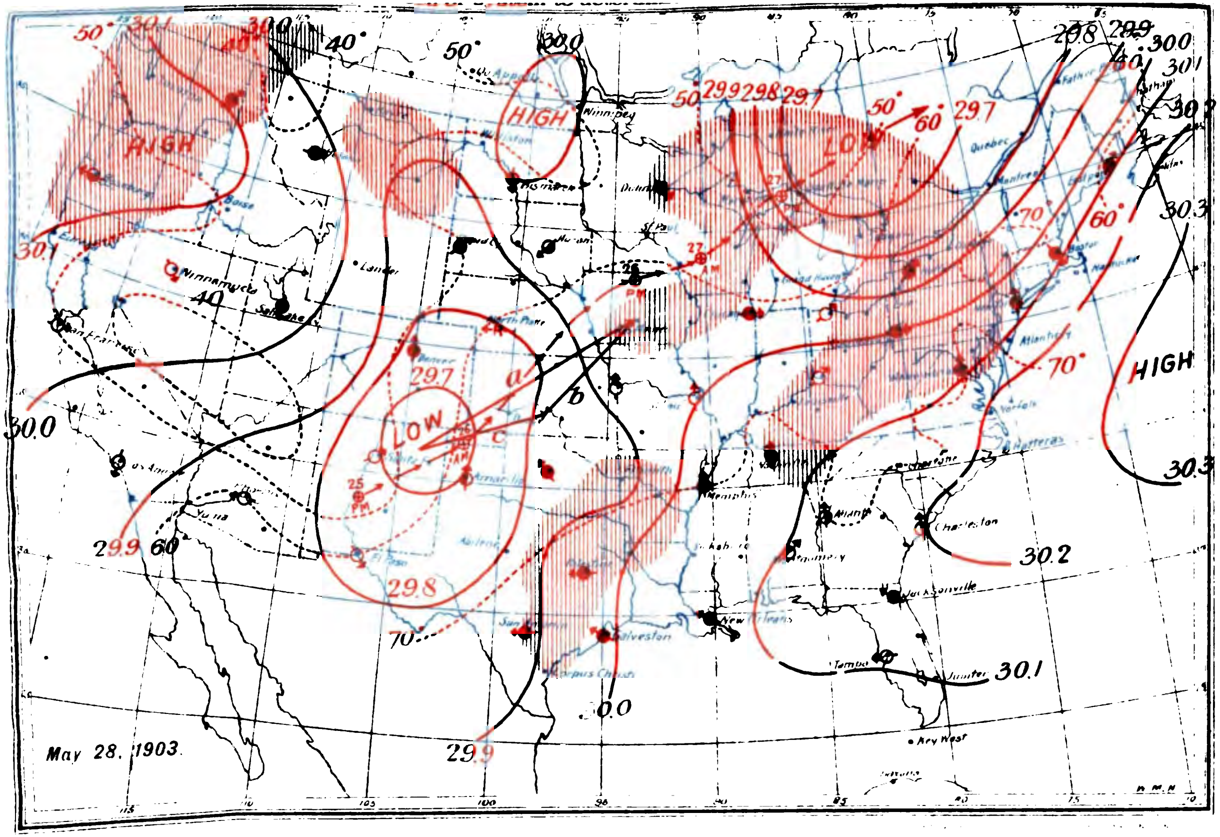


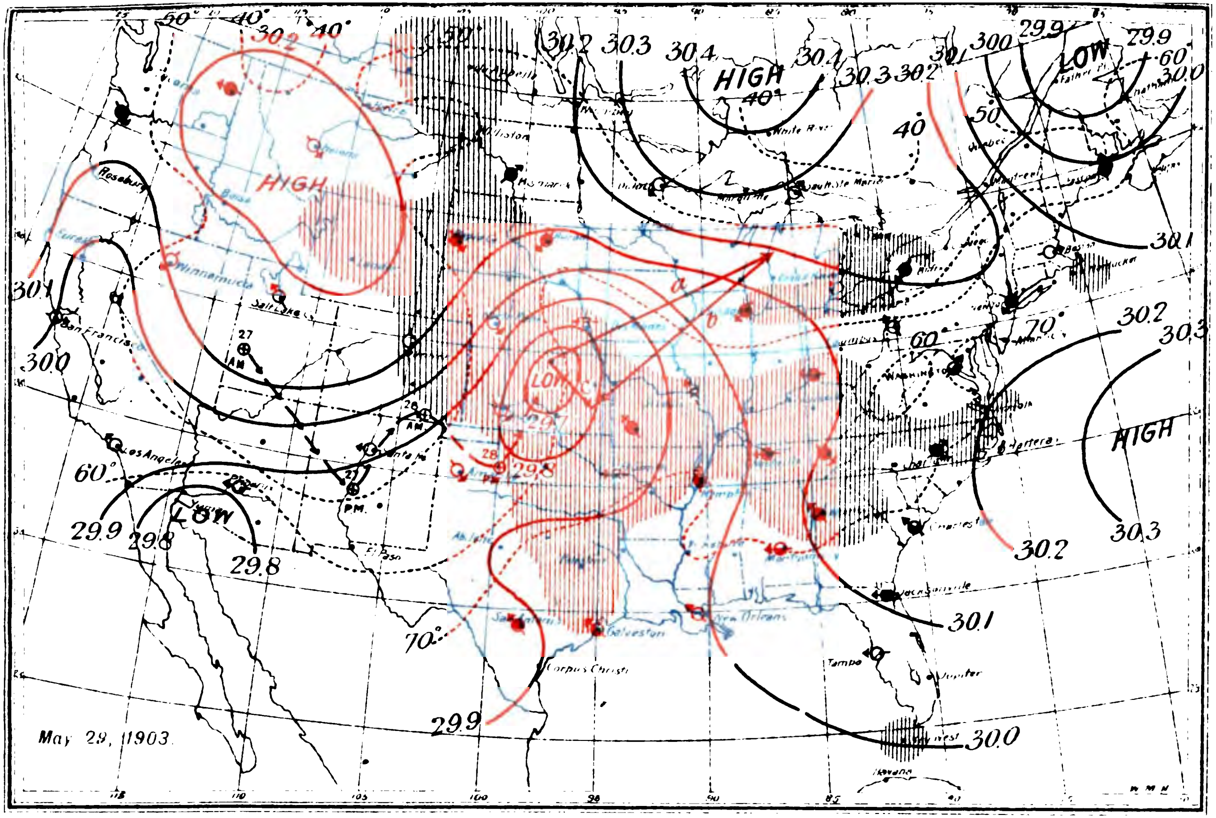

Tacoma
Roseburg
Eureka
San Francisco
Los Angeles
Yuma
Phoenix
Winnemucca
Boise
Helena
Havre
Lander
Salt Lake Cy
Denver
Santa Fe
El Paso
Amarillo
Abilene
Dodge
North Platte
Rapid Cy
Huron
Bismarck
Williston
Qu Appelle
Winnipeg
Duluth
St Paul
Des Moines
St Louis
Ft Smith
Memphis
Vicksburg
Palestine
San Antonio
Corpus Christi
Galveston
New Orleans
Montgomery
Atlanta
Nashville
Louisville
Chicago
Grand Haven
Marquette
Sault Ste Marie
White River
Quebec
Montreal
Oswego
Buffalo
Erie
New York
Boston
Nantucket
Eastport
Father Pt
Chatham
Halifax
Washington
Norfolk
Hatteras
Charlotte
Charleston
Jacksonville
Jupiter
Tampa
Key West
Havana
W. M. H.


HIGH
LOW
LOW
30.4
304.
30.3
30.2
30.2
30.1
30.1
30.0
30.0
30.0
29.9
29.8
29.8
29.7
29.65
29.7
50°
50°
50
50°
60°
60
70°
70°
70
80°
80°
40
a
b
c
Winnipeg
Qu Appelle
Havre
Williston
Bismarck
Huron
Boise
Lander
Winnemucca
Salt Lake City
San Francisco
Los Angeles
Yuma
El Paso
Abilene
Amarillo
Palestine
San Antonio
Corpus Christi
Galveston
New Orleans
Vicksburg
Memphis
St Louis
Nashville
Montgomery
Atlanta
Charleston
Jacksonville
Tampa
Jupiter
Key West
Havana
Norfolk
Hatteras
Atlantic City
New York
Boston
Nantucket
Eastport
Montreal
Quebec
Chatham
Marquette
Moorhead
W. M. H.
115
110
105
100
95
90
85
80
75
70
May 26, 1903.



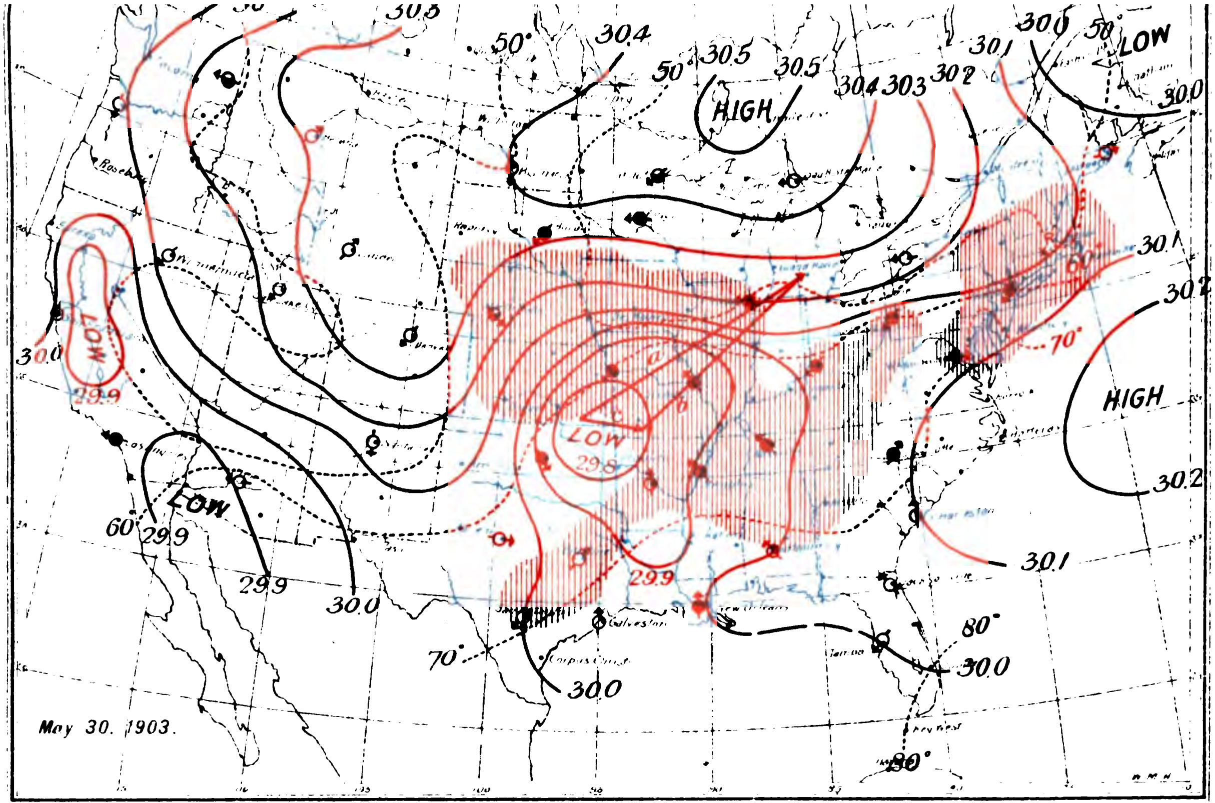
THE NORRIS PETERS CO. PHOTO-LITHO. WASHINGTON, D.C.


May 28. 1903.
HIGH
HIGH
LOW
LOW
HIGH
30.0
29.7
29.8
29.9
30.1
30.2
30.3
29.8
29.9
30.0
30.1
40°
50°
60°
70°
a
b
c
Winnipeg
Quebec
Montreal
Boise
Lander
Winnemucca
San Francisco
Yuma
El Paso
Amarillo
Abilene
Denver
North Platte
St. Paul
Duluth
Bismarck
Memphis
Atlanta
Montgomery
Charleston
Jacksonville
New Orleans
Galveston
Corpus Christi
Tampa
Jupiter
Key West
Hatteras
Norfolk
Atlantic City
Nantucket
Boston
Eastport



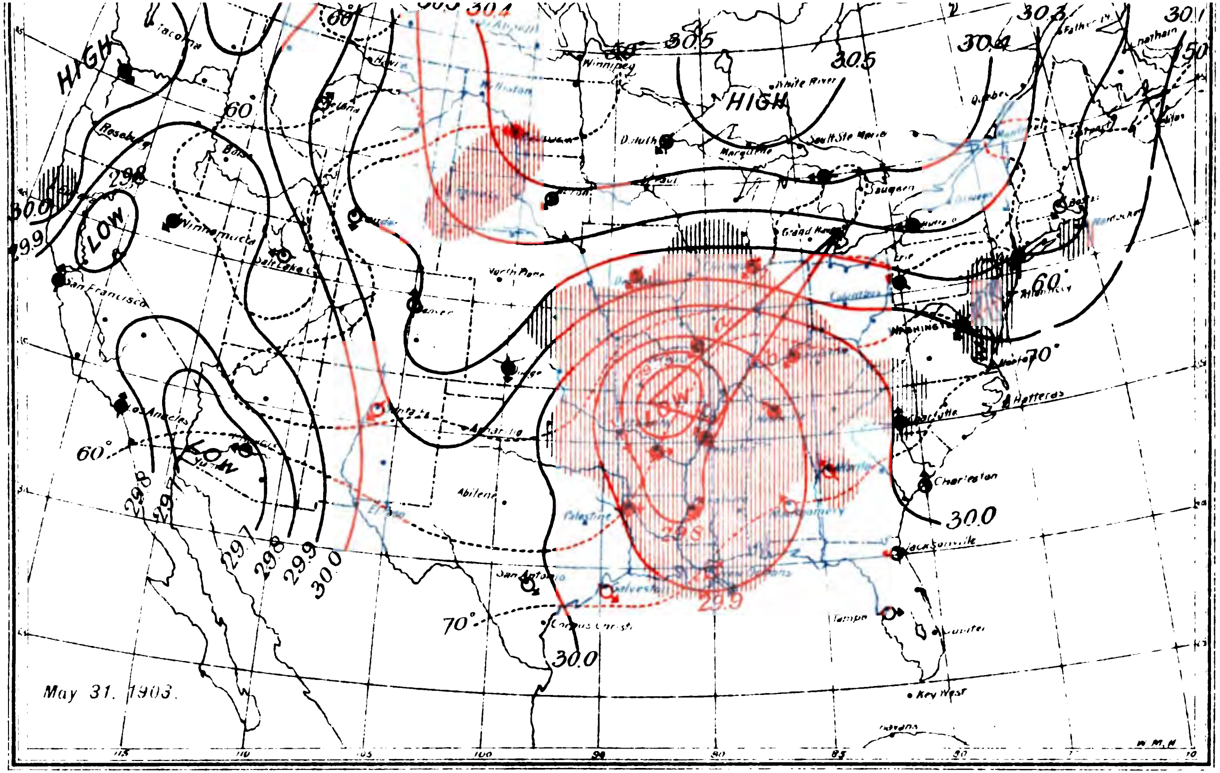
May 29, 1903.

HIGH
HIGH
HIGH
LOW
LOW
LOW
30.2
30.3
30.4
30.4
30.3
30.2
30.1
30.0
29.9
29.9
60°
30.0
30.1
30.2
30.3
30.2
30.3
30.1
30.0
29.9
29.8
29.9
29.8
29.8
29.7
30.1
30.0
50°
40°
40°
30.2
40°
50°
40°
40°
50°
60°
70°
60°
70°
60°
a
b
27
AM
28
AM
28
27
PM.
Roseburg
Eureka
San Francisco
Los Angeles
Winnemucca
Salt Lake
Boise
Williston
Bismarck
Sault Ste Marie
White River
El Paso
Abilene
San Antonio
Galveston
Corpus Christi
New Orleans
Montgomery
Memphis
Washington
Hatteras
Charleston
Jacksonville
Tampa
Jupiter
Key West
Havana
Quebec
Montreal
Nantucket
Boston
Yuma
Phoenix



May 30. 1903.

HIGH
HIGH
LOW
LOW
LOW
LOW
29.8
29.9
29.9
29.9
29.9
29.9
30.0
30.0
30.0
30.0
30.0
30.0
30.0
30.1
30.1
30.1
30.2
30.2
30.2
30.3
30.4
30.4
30.5
30.5
30.5
50°
50°
50°
60°
70°
70°
80°
80°
a
b
c
Roseburg
Galveston
Corpus Christi
New Orleans
Tampa
Key West
Charleston



May 31. 1903.

HIGH
LOW
HIGH
LOW
LOW
30.0
29.9
29.8
29.7
30.4
30.5
30.5
30.4
30.3
30.1
30.0
29.9
29.8
60°
70°
60
Tacoma
Roseburg
San Francisco
Winnemucca
Salt Lake City
Boise
Los Angeles
Yuma
Denver
North Platte
Amarillo
Abilene
El Paso
San Antonio
Corpus Christi
Palestine
Galveston
Winnipeg
Williston
Duluth
Marquette
Sault Ste Marie
White River
Saugeen
Grand Haven
Erie
Quebec
Washington
Atlantic City
Norfolk
Hatteras
Charleston
Jacksonville
Tampa
Jupiter
Key West
Havana
115
110
105
100
95
90
85
80
75
70
W. M. H.

become shorter and Y_2 very much longer, and, at the same time, the ngle made by these lines will increase. From which it follows that value of 1 centimeter for each tenth of an inch increase in pressure est meets the requirements in this case.

Charts IV, V, VI, VII, VIII, IX, and X illustrate the use of the ystem in practical forecasting to determine the probable direction nd rate of movement of storm centers. In these charts the vector a) is the normal storm track, (b) the resultant of the pressure actg toward the storm center from all directions, and (c), the resultant f (a) and (b), the probable path the storm center will follow in the cceeding twenty-four hours.

DISCUSSION.

Mr. **Chaffee**. The paper we have just heard read by Mr. Bowie is o my mind along those practical lines that open up many possibilities r improving weather forecasts. Any work the success of which epends largely upon the experience of those engaged in it suffers ore or less by the loss by death or otherwise of the person or persons onnected with that work who have acquired the necessary experience o be successful in it. Unfortunately for the art of weather foresting, some of the best forecasters of the past have left but little s the result of their study and research for the benefit of those who llow in their work. The man who can devise methods to raise the rcentage of verification of weather forecasts even 1 per cent is ntitled to nearly, if not quite as much, credit as the man who can ake two blades of grass grow where one grew before. And as his paper of Mr. Bowie's will, in my opinion, ultimately mean much o the Bureau, it leads me to suggest that our work as weather foresters and the work of those who follow us might be materially ided if, say, six or eight of our local and district forecasters who ake the best record in each calendar year were required to prepare statement for publication in the bulletins of the Bureau, setting orth the methods and rules upon which their successful forecast ecords were made. Such a course would eventually provide information that would be of incalculable value to the future forecasters f the Bureau, and while each of such papers as is suggested might ot contain anything of special value, if any one of them should ring out something new or valuable in our work it would mean uch to the Bureau and more to the world.

Professor **Moore**. Mr. Bowie's paper is a peculiarly significant one in this light, that it was written by one who has led all the local forecasters of the service during the past three or four years. I would commend it to you for study in the published proceedings because of that fact.

TEMPERATURE FORECASTS AND THEIR RELATION TO IRON ORE SHIPMENTS DURING THE LATE FALL AND EARLY WINTER MONTHS.

By Mr. H. W. **Richardson**, *Duluth, Minn.*

The purpose of this paper is to present briefly an additional illusration as to how special interests may be studied and benefited in a ractical way by the use of our forecasts.

For many years, near the close of the navigation season, the various iron-ore docks in Duluth and vicinity (which includes Two Harbors, Minn., and Superior, Wis.) have experienced more or less trouble on account of frost penetrating the ore.

When freezing occurs the ore must be thawed by steam, which is a very expensive and tedious process, besides the freezing causes aggravating delay in the loading of the vessels. Delays are serious affairs and likewise expensive to the vessel owners. The operating cost of most of the boats exclusively engaged in the ore trade averages close to $200 per day whether in transit or tied to a dock. The delay of but a few days and the loss of a trip or two quickly runs into money and therefore materially affects the season's profits.

The idea occurred to the writer that if the various ore-dock officials could be apprised as to the likelihood of changes either from mild t freezing temperatures and below (in addition to other than technica cold waves), or periods of steady and severe cold, or mild weather following a period of cold, and the probable degrees of temperature an duration of these conditions, such forecasts would be of value t those engaged in this traffic, provided the information be furnished sufficient time in advance.

It might not be out of place to mention that in the season of 190 the ore docks in Duluth and vicinity shipped over 15,000,000 tons o iron ore to lower lake ports, the valuation of the ore being abou $35,000,000.

This idea was put in practice during the months of Octobe November, and December, the critical period. The superintenden of each ore dock in Duluth, Superior, and Two Harbors was furnished special forecasts of the character mentioned, either by telephone or telegraph, as often as seemed necessary.

On such special occasions, particularly when cold waves or lo temperatures were forecast, the shipments from mines to docks wer regulated as nearly as possible according to the vessel tonnage waitin or expected on given dates. The ore was moved directly from th mines to the boats instead of being allowed to stand in the cars or t be dumped into ore pockets, as is the custom in mild weather.

Mild temperature forecasts in the frost season are as valuable a those for low temperatures, for the companies are thus able to haste preparations for rush orders at a critical time when they would otherwise be somewhat timid and run chances of causing vessel delays b not having sufficient ore at docks. It should be stated that the or for any one boat must be from the same mine, in order that there be no difference in its grades, as in these ships the cargo is carried in one large and undivided hold.

Of course there is usually a marked decline in the traffic as the close of the season approaches, but in the months of October, November, and December, 1903, the iron-ore cargoes from docks mentioned aggregated 2,588,651 tons, valued at over $6,000,000.

Assuming that the net tonnage of ore-carrying vessels now in the trade at the head of the Lakes averages about 5,000 tons, it would require 518 vessels to transport the ore handled in those three months. The net tonnage per ore car and the number of cars per train vary somewhat among the local railroads engaged in transporting ore from mines to docks, usually ranging from 30 tons for wooden to 50 tons for steel cars, the general average being close to 45 net tons, while the number of cars to the train averages 46. The tonnage in these three months would fill 57,525 cars, making about 1,251 trains. The cost of thawing frozen ore runs from $1 to $3 per car and sometimes more, depending upon the quantity and degree of frost in the ore, the air temperature at the time, and the granular nature of the ore.

The superintendent of the Duluth and Iron Range Railway (an important ore road which also operates the docks at Two Harbors) stated that it would be a difficult matter to place a precise money valuation on the warnings and special temperature forecasts, but that the information given was undoubtedly worth many thousands of dollars to the companies interested. The economy included the saving in vessel delays, quick dispatch from mines to docks, the controlling of mine output to tonnage desired for vessel orders, and the easier handling of ore at docks by reducing the item of freezing and consequent thawing to a minimum or avoiding that trouble altogether.

DISCUSSION.

Professor **Moore**. I would like to know from Mr. Richardson what use they make of the forecast if there is to be a hard frost. How do they change their operations as a result of that knowledge?

Mr. **Richardson**. The ore at the mines is piled up in large stock piles. The docks are a comparatively short distance from the mines and the trains run in great numbers to the docks every day and they load and unload in a very short time. When they get word that the temperature is likely to go to 25° or less they regulate the loading of the cars and the number of trains from the superintendent's office in accordance with the word they get. They do not fill up the docks. When they have a boat waiting at the dock they will throw the ore immediately into the dock pockets and from there into the boat; in other words, by the rapid handling they aim to prevent the ore from freezing in cars or on the docks.

DISTRIBUTION OF FORECASTS BY TELEPHONE.

By Dr. George M. Chappel, *Des Moines, Iowa.*

You are all familiar with the various schemes which have been inaugurated since the establishment of the service for the distribution of the daily forecasts. In the early days of the Signal Service the distribution was effected by "farmers' bulletins," which were seldom if ever seen by a farmer. Then came the weather flags, followed within the past few years by the rural free delivery mail service, which enabled us to place the forecast some time during the day at the door of thousands of farmers. This was thought to be an ideal method of distribution, and it is still very helpful in many places; but now we have the rural telephone, which is a long step in advance of the mail service, placing the forecast inside of the farmer's door at an earlier hour. This is in many respects the most satisfactory method that has been adopted. It is the quickest and cheapest, causing less work at the section center and at the subdistributing points.

I feel that some degree of success has been attained in Iowa during the past year in having forecasts and special warnings distributed by rural telephone, and possibly the method followed for the inauguration of such service may be of interest to some of the members present. I trust that it will be, as that was my only object in writing this paper.

In Iowa, and I presume it is the same in other States, the telephone companies are taxed, and under the laws of the State all companies are required to make a report on or before a certain date each year to the secretary of state, giving the names and addresses of the officers and directors of the company and the number of miles of line owned and maintained by each. A list of all companies doing business in the State, together with the names and addresses of the officers, is kept at the office of the secretary of state, from whom a copy can be obtained.

After obtaining a copy of the list a circular letter was sent to the secretary or manager of each company, asking if they would be willing to distribute the forecasts over their rural lines without expense to this Bureau, in case the Chief should authorize the forecasts sent to them by telegraph at Government expense. The circular letter also called for information as to whether the lines of the company extended to town or country or both; names of terminal towns and all intermediate towns through which the lines passed; whether or not the lines made connection through an exchange with the lines of any other company, and if so names of such connecting lines and of towns at which connection was made; and last, the number of telephones on each line to which the forecasts would be sent.

After the receipt of this information it was an easy matter to start the distribution, by selecting such companies as had the most rural subscribers and gave the widest distribution.

There are at present over 1,200 telephone companies in the State of Iowa, and the number is being increased by 300 to 500 a year. At this rate it will be but a short time before there is a veritable network of telephone lines over the State, and every progressive and up-to-date farmer will have an instrument in his home.

It is known to be a fact that over 50 per cent of the farmers of the State now have telephones in their homes, and I am pleased to be able to state that over 50 per cent of those having instruments are receiving the forecast at or before noon each day.

DISCUSSION.

Mr. J. WARREN SMITH. In Ohio there is a telephone company which has an organization combining all the local or independent telephone lines, so that a man wanting to telephone from Cincinnati to Cleveland will perhaps go through four of these independent lines, making it possible to reach all over the State. Now, in May my modest friend at the left (Mr. Kenealy) made an arrangement with the president of that company to distribute the daily forecast from Cleveland into the northeastern part of Ohio. On June 6 the service was extended all over Ohio, so that from the Weather Bureau offices at Cleveland, Toledo, Sandusky, and Columbus, and one special distributing point at Dayton, we are able to put the daily forecast within reach of 175,000 to 200,000 subscribers, fully 40 per cent of whom are farmers. The Bell Company saw what their rivals were doing, and in June they also began the distribution, and are now extending very rapidly into the farming districts. They have now probably about 100,000 subscribers and 900 toll stations, and between 10,000 and 11,000 farmers on their line. We have furnished them with a tin card holder and a lot of blank cards for each toll station where the forecast is posted. In addition to that they have advertised very generally. They have sent out circulars to their subscribers in the country districts giving them the information that they can receive the forecast in the morning soon after 10 o'clock. The Pittsburg Printing Telegraph Company has very recently begun the distribution in the eight southeastern counties of Ohio that the Bell Company does not reach. They get the forecast from Pittsburg. It is safe to say that over 60,000 farmers in Ohio get the weather forecast within an hour after it is issued from Washington every day. And all through the efforts of Mr. Kenealy.

Mr. **Burns**. The honorable the Secretary of Agriculture, in an address delivered before the second convention of Weather Bureau officials, said:

> The time is coming when we will send a message every morning to every producer and tell him what we know about the weather.

On the same occasion the Chief of Bureau said:

> There is no use in collecting information if you can't distribute it.

The rapid development of telephone systems is making the prophecy possible.

I have long been impressed with the importance and effectiveness of this means of dissemination, and my principal effort has been directed toward its accomplishment in the Illinois section.

The daily forecast card was the principal effective means of dissemination before the installing of the rural free-delivery system. The rural free-delivery system has not, I believe, fulfilled expectations, as in many instances the carriers depart before the receipt of the forecasts. In an investigation of the effectiveness of the forecast-card system a distributing center with ample railroad facilities was selected (reference is made to the Springfield, Ill., center), and the following results were disclosed: Six per cent of the cards sent out were received by or before noon; 8 per cent between noon and 1 p. m.; 10 per cent between 1 and 2 p. m.; 11 per cent between 2 and 3 p. m.; 16 per cent between 3 and 4 p. m.; 24 per cent between 4 and 5 p. m.; 11 per cent between 5 and 6 p. m., and 13 per cent between 6 and 7 p. m.

When it is considered that the receipt of the card at the post-office does not indicate a dissemination of the information to the rural interests, its usefulness is limited in very great measure.

The census of 1900 has Illinois credited with 264,000 farms, fully one-half of which, it is believed, are now supplied with telephones. The work of building new lines and connecting the different exchanges is rapidly progressing.

Six hundred and eighteen independent telephone exchanges and farmers' lines have been communicated with, and most gratifying results have ensued. A corporation covering an equally large field has not been considered. In response to my letters to independent exchanges and farmers' lines, requests representing 150,000 telephones and several hundred farmers' lines, and covering 500 or more small towns and the surrounding rural territory, have been received. The figures stated represent data only partially furnished, some correspondents supplying all information requested, while many neglected to do so, and it is believed that when all the details of the service are worked out, a showing approximating 200,000 subscribers receiving the daily forecast will be made.

That the service will be appreciated by the farmer is beyond question or doubt, as expressions received directly and indirectly show, and I know of no means whereby the Bureau will become more popular in public esteem than by giving the weather information to the rural interests in such time as to be of value. By means of the telephone it is believed that the information will be made available each day by or before 10.30 a. m.

A very important matter to be considered in this connection is the growing reluctance of many postmasters to perform the gratuitous service of forecast-card distributors. Some are faithful in the performance of the work, while many grow indifferent, and difficulty is experienced in maintaining the service at the proper standard. With the telephone exchanges it is a matter of personal interest, as their service becomes more valuable to their subscribers the greater the benefits afforded. It has been represented to the telephone exchanges that the giving of the weather information to their patrons would often be a determining factor when dealing with an irresolute subscriber, and that the argument is potent is evidenced by the great number of requests received. The telephone exchanges have mostly entered into the arrangement with marked cordiality.

PRACTICAL RULES FOR FORECASTING FLOOD-CREST STAGES FOR CAIRO, ILL.

By Mr. P. H. Smyth, *Cairo, Ill.*

The questions have been asked me a number of times, "How do you go about making your river forecasts for Cairo?" "Upon what do you base your predictions of crest stages for Cairo?" These questions may seem easy to answer, but to reply to them so as to unfold the method, or methods, clearly, is quite difficult. The subject of crest-stage forecasting is a complex one. There are so many conditions to be considered when making forecasts of crest stages for Cairo that it is exceedingly difficult, if not wholly impossible, for the forecaster to portray his methods so that another could use them in their entirety. In this paper I shall endeavor to explain as clearly as I can the methods in use at Cairo for predicting crest stages for that place. I have limited my subject to crest-stage forecasting for Cairo because of the peculiar position it occupies in times of great floods. Cairo is situated at the confluence of two great rivers, and at such times it is the key to flood conditions in the lower Mississippi River. I have given the matter much careful study; I have called in the assistance of a professor of mathematics, but after all I have found that the simplest rule used with a good share of intuitive knowledge gives the best results.

The data upon which river forecasts made at Cairo are based are the accumulated records (gage readings) of the important rises in

ɜt, which have been supplemented at Cairo since 1894 by a
ɔrd of the gage readings and rainfalls, as far as practicable,
incipal stations located on the main rivers and tributary
(See Exhibit 1.) In addition to the daily record a separate
kept of each considerable rise. These data are almost inva-
plied empirically in predicting crest stages for Cairo. For
ıonths I tried predicting river changes from hydrographic
Although the hydrographs show the rise and fall very satis-
the amounts of the rises and falls and the stages attained
o clearly presented, and after using the data in the form
in Exhibit 1, I now prefer the latter method.

eral rainfall alone is of little practical value in forecasting
ges in the Cairo district.

late fall and early winter a record is kept at the Cairo office
llowing conditions: (1) Whether or not the precipitation
several river territories is above or below the average or of
l amount; (2) temperature conditions following general
nows; (3) time elapsing between general rains or snows.

ject in keeping a record of these conditions is to get an idea
to expect in the event of heavy rains in the late winter and
onjecturing that upon weather and temperature conditions
e fall and early winter depend to some extent the intensity
onditions of late winter and spring. Just what this connec-
am not at present prepared to say. I have tabulated con-
data upon the subject, but they are not as yet in such shape
rant a definite statement being based upon them.

well-known fact that rises to dangerous flood stages in the
the Cairo district rarely, if ever, result from a single rain-
en several moderately heavy rainfalls. Such rises are due
ıvariably to a series of long-continued rainstorms. The
ge of this fact is taken advantage of in predicting crest
r Evansville and some other points, but the rules used for
g crest stages for these points are not practicable for Cairo.
dict whether or not the river is going to rise or fall at a
oint is, as a rule, a very simple proposition, but to be able
t to a nicety the amount of the expected rise or fall and the
ıch rise or fall is to continue is not so simple. Crest-stage
ns for Cairo are based mainly upon the gage readings at
ti, Mount Carmel, Nashville, Chattanooga, and St. Louis.
that important rises sometimes occur almost simultaneously
f the points mentioned above, or within a few days of one
except in the case of the Mississippi at St. Louis, which
ows an important rise when the Ohio and its tributaries are

fect that each tributary has upon the main stream is not

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tive effect of different rivers in predicting freshet waves might be
though incorrectly) to be nearly proportional to their drainage areas.
rtant to note that the average slope in the drainage basins and the
ty of the soil determine largely the action of rivers in producing floods.
Chief Signal Officer, 1891.)

a rise is in progress at headwaters the stages reached or
be reached are compared with those of previous practically

corresponding rises, all things considered, viz, time of year, cond tions preceding as regards rainfall, heights of the rivers througho their entire lengths, and temperature conditions. When this compar ison is made and weather conditions are unsettled, a prediction i made according to the amount of water then in sight, as indicated b the comparison. It is well to make the comparison with the rise o rises recently preceding the rise in progress, for the reason that rive improvements cause like conditions to have different effects. This however, does not at the present time apply so much to Cairo as i does to points on the Mississippi River below Cairo.

When a prediction is made from such a comparison that the wate in sight indicates a certain stage by a certain day, this prediction i supplemented from time to time as occasion requires. As an illus tration, let us assume that the stages reached at headwaters indicate by comparison, a stage of 50 feet for Cairo within seven days. Tha stage is then forecast to occur within the period mentioned and thi prediction supplemented from day to day as conditions warrant. I is sometimes the case that river and weather conditions are such tha a crest stage can be forecast for Cairo as soon as it becomes know what stages are expected at headwaters. It must be borne in mind however, that a prediction made for a point on the lower river fro observed gage readings at places farther up the river, particularly places near headwaters, is subject to more or less error on account o the water entering the river between stations.

The crest at Cairo is usually flat, so that when the rate of rise shows a slight falling off, the number of days the rise is likely to continue is determined from existing conditions, the additional rise approximated, and the forecast of crest stage made. On important rises the decrease in the rate of rise is usually very uniform, therefore the amount of the additional rise during the four to six days, or even longer period, preceding a crest can be forecast with a considerable degree of certainty. Exhibit 2 shows the rates of several important rises after the rate of rise had commenced to diminish. When the length of time that the river at Cairo during a flood period is above 40 feet (the former danger line) is considered, the impracticability of always predicting with certainty the crest stage for Cairo more than a few days previous to its occurrence is apparent. To better illustrate this a brief history of the flood of the spring of 1897 is given:

The flood of the spring of 1897 was ushered in by a 16.8-foot rise at St. Louis from January 3 to 7, which increased the stage at Cairo from 11.4 feet on January 4 to 28.2 feet on January 9. Before the effects of this rise had passed off a rise out of the Cumberland set in. The Cumberland rise was augmented by rises out of the Wabash and Mississippi from January 18 to 23. The river at Cairo fell from 26.5 feet on January 24 to 14.0 feet on February 4. Rises commencing at Nashville and Chattanooga on February 1, and at Cincinnati on February 3, together with a moderate rise in the Mississippi, gave Cairo 34.2 feet by February 15, followed by a fall to 32.2 feet by February 22, when rises in the Cumberland, Tennessee, Wabash, and Mississippi started the river at Cairo up again, and before the crests of these rises had passed Cairo a rise from the upper Ohio set in, which, together with rises out of the Wabash, Cumberland, and Mississippi, increased the stage at Cairo to 48.6 feet on March 11. A slight fall followed which lasted about thirty-six hours and amounted to 0.2 foot. This was followed by a rise which continued until March 25, when the crest stage of 51.7 feet was reached. The river remained at that stage for four days, then gradually receded, sometimes coming to a stand and sometimes rising one or two tenths of a foot, until it passed below 40 feet during the night of April 27–28. On this rise the river at Cairo was above 40 feet for fifty-nine days. During the flood of 1882 the river at Cairo was above 40 feet for eighty-one days; in 1890 it was above that stage sixty-nine days.

The time of flood crest from Cincinnati to Cairo is six days; from Chattanooga to Cairo, six days; from Nashville to Cairo, three days, and from St. Louis to Cairo, about four days.

The flood plane is greatest at Cairo when the greatest twenty-four-hour rises occur at such times at the headwaters of the several main rivers and tributaries as to bring the freshet waves together. A rise of 2 feet or more at headwaters, requiring as many days after the great rush of water, seems to have little effect by the time it reaches the lower river. Moderate floods—those not reaching danger-line stages—are sometimes caused by tributaries to the lower Ohio River, together with a rise to danger-line stages in the Mississippi River above Cairo.

I have found that the change at Paducah, whether plus or minus, has a slightly greater effect at Cairo than has the change at Chester. When the Ohio is rising at Cairo, the rise will be more if the Mississippi at St. Louis is rising. The effect is corresponding when the rivers are falling.

Temperature conditions have a marked effect upon flood conditions. Severe cold weather will materially check a rise and modify the flood plane by a foot, or even considerably more.

Some persons attempt to forecast crest stages at various points as soon as heavy rains are reported in the upper watersheds. I have known some of them to miss the mark as much as 5 feet. Yet, when the next season sets in, they come up just as smiling as ever, and as confidently make a forecast for the coming flood. If they had the data upon which to base their predictions there would be some excuse for their eagerness, but, as a rule, when one of them is questioned as to what he bases his predictions upon, he will answer: "Oh, I see by the newspapers that they have been having some heavy rains up above." Such predictions are most pernicious and do considerable harm. I hope that the day is not far distant when newspapers will publish weather and river forecasts emanating from *official sources* only. Surely, if anyone is in a position to predict these conditions with any degree of certainty, it is he that makes it a life work, and that is in possession of data upon which to base his forecasts.

EXHIBIT 1.—*Daily record of heights of rivers, and twenty-four hour changes, in feet and tenths, and twenty-four hour rainfalls, in inches and hundredths.*

River and station.	Distance from Cairo.	Days from Cairo.	Danger line.	Highest water.		Lowest water.	
				Date.	Feet.	Date.	Feet.
Ohio River:	*Miles.*		*Feet.*				
Pittsburg	964	11	22	Feb. 6, 1884	33.3	Sept. 28, 1881	−1.3
Parkersburg	784	9	36	Feb. 9, 1884	53.9	Oct. 30, 1879	.0
Cincinnati	498	6	50	Feb. 14, 1884	71.1	Sept. 17–19, '81	1.9
Louisville	366	5	28	Feb. 15, 1884	46.7	Oct. 25–31; Nov. 1–8, 16–17, 1895	1.8
Evansville	183	3	35	Feb. 19, 1884	48.8	Nov. 7–8, 1895	−.3
Paducah	46	−1	40	Feb. 13, 1884	54.2	Oct. 30–Nov. 4, 1895	−.7
Cairo	0	0	45	Feb. 27, 1883	52.2	Dec. 24, 1871	−1.0
Cumberland River, Nashville	215	3	40	Jan. 22, 1882	55.3	Oct. 15–16, '78	−.4
Tennessee River:							
Chattanooga	495	6	33	Mar. 11, 1867	58.6	Sept.,[a] 1837 Sept. 14, 1881 Sept. 19, 1883	.0
Florence	266	3	16	Mar. 19, 1897	32.5?	Oct. 24, 1872	−.8?
Johnsonville	140	+1	21	Mar. 20, 1897	48.0	Oct. 6–20, '97	−.3
Wabash River, Mount Carmel	178	......	15	Apr. 7, 1884	28.3	Nov. 8–23, '95	−.2
Mississippi River:							
St. Paul	833	12	14	Apr. 29, 1881	19.6	Mar. 19, 20, 22, 1896	−.9
Davenport	499	7	15	June 27, 1892	19.4	Nov. 30, 1898 Jan. 6, 1890	−.8
St. Louis	168	4	30	June 28, 1844	41.4	Jan. 2, 1900	−2.6
Chester	97	−2	30	......	40.0	Jan. 3, 1900	−4.1
New Madrid	......	......	34	, 1897	40.3?	......	......
Memphis	230	3	33	Mar. 20, 1903	40.1	Nov. 9, 1895	−2.7
Missouri River:							
Omaha	856	......	18	Apr. 24, 1881	23.8	Dec. 3, 1867	1.6
Kansas City	569	8	21	June 20, 1844	37.0	June 6, 1874	−.1

River and station.	Apr. 1, 1904.			Apr. 2, 1904.			Apr. 3, 1904.			Apr. 4, 1904.		
	Stage.	Change.	24-hour rainfall.	Stage.	Change.	24-hour rainfall.	Stage.	Change.	24-hour rainfall.	Stage.	Change.	24-hour rainfall.
Ohio River:												
Pittsburg	10.0	+1.4	0.98	21.9	+11.9	0.02	18.0	−3.9	T.	13.7	−4.3	......
Parkersburg	17.0	......	.02	21.0	+4.0	.02	31.0	+10.0	T.	34.8	+3.8	......
Cincinnati	44.8	+1.0	.20	42.8	−1.5	......	39.9	−2.9	......	37.7	−2.2	......
Louisville	21.0	+1.8	.04	20.3	−.7	......	19.0	−1.3	......	16.5	−2.5	......
Evansville	39.3	.0	.04	39.5	+.2	......	39.8	+.3	......	39.8	.0	......
Paducah	42.6	+1.3	.20	43.6	+1.0	......	44.3	+.7	......	44.7	+.4	......
Cairo	47.6	+.8	1.01	48.2	+.6	......	48.7	+.5	......	49.0	+.3	......
Cumberland River, Nashville	31.9	−1.9	.62	19.1	−12.8	......	19.2	+.1	......	15.4	−3.8	......
Tennessee River:												
Chattanooga	9.0	−1.8	.14	8.1	−.9	.06	7.2	−.9	......	6.6	−.6	......
Florence	11.3	−2.5	1.92	10.3	−1.0	......	8.8	−1.5	......	7.7	−1.1	......
Johnsonville	26.9	−.8	.76	25.8	−1.1	......	24.4	−1.4	......	22.3	−2.1	......
Wabash River, Mount Carmel	27.0	+.5	.10	27.1	+.1	......	26.6	−.5	......	26.1	−.5	......
Mississippi River:												
St. Paul	5.8	−.2	.01	5.6	−.2	......	5.5	−.1	......	5.8	+.3	......
Davenport	9.1	−.1	.16	9.2	+.1	......	9.0	−.2	......	8.7	−.3	......
St. Louis	25.0	−.1	1.14	24.5	−.5	......	24.3	−.2	......	23.7	−.6	......
Chester	22.7	−.2	.40	22.5	−.2	......	22.2	−.3	......	21.8	−.4	......
New Madrid	36.4	+.7	.08	37.2	+.8	......	37.8	+.6	......	38.3	+.5	......
Memphis	32.1	+.9	.82	32.7	+.6	......	33.4	+.7	......	34.0	+.6	......
Missouri River:												
Omaha	6.8	(?)	.01	7.2	+.4	......	8.4	+1.2	......	8.6	+.2	T.
Kansas City	9.3	−.4	.02	8.9	−.4	......	8.7	−.2	......	8.4	−.3	......

[a] Date not known.

NOTE.—T in rainfall column indicates an inappreciable amount.

HIBIT 1.—*Daily record of heights of rivers, and twenty-four hour changes, in feet nd tenths, and twenty-four hour rainfalls, in inches and hundredths*—Con.

River and station.	Apr. 5, 1904.			Apr. 6, 1904.			Apr. 7, 1904.		
	Stage.	Change.	24-hour rainfall.	Stage.	Change.	24-hour rainfall.	Stage.	Change.	24-hour rainfall.
River:									
Pittsburg	10.8	−2.9	......	9.0	−1.8	......	7.8	−1.2	......
Parkersburg	32.7	−2.1	......	27.0	−5.7	T.	19.8	−7.2	0.34
Cincinnati	38.0	+ .3	......	41.0	+3.0	0.06	42.1	+1.1	.24
ouisville	14.1	−2.4	......	13.1	−1.0	.10	14.4	+1.3	.06
vansville	39.3	− .5	......	38.5	− .8	.34	37.8	−1.2	......
Paducah	44.6	− .1	......	44.0	− .6	.30	43.4	− .6	......
airo	49.1	+ .1	......	48.9	− .2	.20	48.5	− .4	......
berland River, Nashville	13.2	−2.2	......	11.7	−1.5	.02	10.4	−1.3	......
essee River:									
Chattanooga	6.0	− .6	......	5.6	− .4	.50	5.4	− .2	.10
lorence	6.6	−1.1	......	5.7	− .9	.26	5.5	− .2	......
ohnsonville	19.4	−2.9	......	17.1	−2.3	.14	15.1	−2.0	......
ash River, Mount Carmel	25.6	− .5	......	25.3	− .3	.24	25.2	− .1	T.
ssippi River:									
t. Paul	6.2	+ .4	0.12	6.5	+ .3	......	8.4	+1.9	......
avenport	8.4	− .3	......	8.2	− .2	......	7.9	− .3	......
t. Louis	23.1	− .6	......	22.5	− .6	.24	21.8	− .7	......
hester	21.3	− .5	......	20.7	− .6	.20	20.1	− .6	......
ew Madrid	38.5	+ .2	......	38.6	+ .1	.48	38.6	.0	......
emphis	34.7	+ .7	......	35.5	+ .8	.26	36.7	+1.2	......
uri River:									
naha	8.4	− .2	.04	8.6	+ .2	......	8.7	+ .1	.56
nsas City	9.0	+ .6	.01	9.7	+ .7	.01	9.8	+ .1	T.

River and station.	Apr. 8, 1904.			Apr. 9, 1904.			Apr. 10, 1904.		
	Stage.	Change.	24-hour rainfall.	Stage.	Change.	24-hour rainfall.	Stage.	Change.	24-hour rainfall.
iver:									
tsburg	7.0	−0.8	......	6.6	−0.4	0.20	7.3	+0.7	0.02
rkersburg	15.0	−4.8	0.01	13.6	−1.4	.14	12.4	−1.2	T.
cinnati	40.8	−1.3	.08	37.4	−3.4	.22	32.8	−4.6	.08
uisville	15.2	+ .8	.26	14.5	− .7	.01	12.4	−2.1	.12
ansville	36.4	− .9	.18	36.0	− .4	.02	35.5	− .5	.12
ducah	42.5	− .9	.10	41.5	−1.0	......	40.6	− .9	......
iro	47.9	− .6	.03	47.2	− .7	T.	46.5	− .7	T.
erland River, Nashville	9.6	− .8	.01	8.8	− .8	......	8.5	− .3	.02
ssee River:									
attanooga	5.4	.0	.36	5.8	+ .4	......	5.9	+ .1	T.
orence	5.2	− .3	.06	5.7	+ .5	......	5.8	+ .1	......
hnsonville	13.5	−1.6	.04	12.3	−1.2	......	11.5	− .8	......
sh River, Mount Carmel	25.1	− .1	.20	24.6	− .5	.10	24.2	− .4	T.
sippi River:									
. Paul	8.8	+ .4	.02	9.0	+ .2	.78	9.7	+ .7	......
avenport	7.7	− .2	.48	7.8	+ .1	.10	8.0	+ .2	......
t. Louis	20.3	−1.5	.54	21.2	+ .9	.04	22.3	+1.1	......
hester	19.4	− .7	.16	18.8	− .6	......	18.9	+ .1	.01
ew Madrid	38.3	− .3	.06	37.9	− .4	......	37.5	− .4	......
emphis	37.8	+1.1	.10	38.6	+ .8	......	39.0	+ .4	......
uri River:									
maha	8.5	− .2	.24	8.5	.0	......	10.7	+2.2	......
ansas City	10.2	+ .4	.72	10.1	− .1	.28	10.7	+ .6	......

EXHIBIT 2.—*Table showing rates in feet and tenths of several important rises Cairo, Ill., after the rate of rise had commenced to diminish.*

Date.	Stage.	Change.
1897.		
March 11	48.6	+0.1
March 12	48.4	− .2
March 13	48.4	.0
March 14	48.7	+ .3
March 15	49.0	+ .3
March 16	49.4	+ .4
March 17	49.6	+ .2
March 18	50.0	+ .4
March 19	50.4	+ .4
March 20	50.7	+ .3
March 21	50.8	+ .1
March 22	51.1	+ .3
March 23	51.4	+ .3
March 24	51.6	+ .2
March 25	51.7	+ .1
March 26	51.7	.0
March 27	51.7	.0
March 28	51.7	.0
1898.		
January 23	39.8	+1.4
January 24	41.2	+1.4
January 25	42.1	+ .9
January 26	42.7	+ .6
January 27	43.3	+ .6
January 28	43.7	+ .4
January 29	44.0	+ .3
January 30	44.2	+ .2
January 31	44.4	+ .2
March 24	40.9	+2.4
March 25	42.8	+1.9
March 26	43.8	+1.0
March 27	44.7	+ .9
March 28	45.5	+ .8
March 29	46.2	+ .7
March 30	46.9	+ .7
March 31	47.6	+ .7
April 1	48.4	+ .8
April 2	49.1	+ .7
April 3	49.5	+ .4
April 4	49.6	+ .1
April 5	49.6	.0
April 6	49.8	+ .2
1899.		
January 13	33.0	+1.7
January 14	35.4	+2.4
January 15	37.2	+1.8
January 16	37.9	+ .7
January 17	38.1	+ .2
January 18	38.2	+ .1
January 19	38.3	+ .1
January 20	38.3	.0
March 11	43.0	+ .2
March 12	43.4	+ .4
March 13	43.9	+ .5
March 14	44.4	+ .5
March 15	44.7	+ ,3
March 16	45.0	+ .3
March 17	45.2	+ .2
March 18	45.6	+ .4
March 19	45.7	+ .1
March 20	45.8	+ .1
March 21	45.8	.0
March 22	45.9	+ .1
March 23	45.9	.0
March 24	46.0	+ .1
March 25	45.9	− .1
March 26	45.9	.0
March 27	45.9	.0
March 28	46.0	+ .1
March 29	46.1	+ .1
March 30	[a]46.2	+ .1

Date.	Stage.	Change.
1900.		
March 8	27.8	+
March 9	31.2	+
March 10	33.7	+
March 11	35.3	+
March 12	36.6	+
March 13	37.4	+
March 14	38.1	+
March 15	38.7	+
March 16	39.1	+
March 17	39.2	+
March 18	38.9	−
1901.		
April 22	37.0	+
April 23	37.5	+
April 24	38.5	+
April 25	39.5	+
April 26	40.5	+
April 27	41.2	+
April 28	41.8	+
April 29	42.4	+
April 30	42.9	+
May 1	43.1	+
May 2	43.2	+
May 3	43.1	−
1902.		
March 5	29.6	+
March 6	32.3	+
March 7	34.2	+
March 8	35.6	+
March 9	36.8	+
March 10	37.9	+
March 11	39.1	+
March 12	40.0	+
March 13	40.6	+
March 14	41.2	+
March 15	41.7	+
March 16	42.1	+
March 17	42.2	+
March 18	41.9	−
March 30	30.3	+
March 31	32.2	+
April 1	33.5	+
April 2	34.6	+
April 3	35.7	+
April 4	37.0	+
April 5	38.1	+
April 6	38.8	+
April 7	39.2	+
April 8	39.2	
April 9	39.0	−
December 17	31.7	+
December 18	34.0	+
December 19	35.4	+
December 20	36.2	+
December 21	36.8	+
December 22	37.3	+
December 23	37.8	+
December 24	38.4	+
December 25	38.8	+
December 26	39.0	+
December 27	39.0	
1903.		
February 6	30.5	+
February 7	34.3	+
February 8	36.8	+
February 9	38.2	+
February 10	39.2	+
February 11	40.0	+
February 12	40.7	+
February 13	41.1	+
February 14	41.5	+
February 15	42.0	[b]+ .

[a] At 46.2, 6 days, from March 30 to April 4; at 46.1, 4 days, from April 5 to April 8.

[b] Heavy rains.

.—*Table showing rates in feet and tenths of several important rises at , Ill., after the rate of rise had commenced to diminish*—Continued.

ate.	Stage.	Change.	Date.	Stage.	Change.
903.			1903.		
	42.9	[a]+0.9	April 22	45.2	+0.1
	43.5	+ .6	April 23	45.2	.0
	43.5	.0	April 24	45.2	.0
	43.3	− .2	April 25	45.0	− .2
	42.8	+ .2	June 5	35.1	+2.2
	43.3	+ .5	June 6	37.4	+2.3
	44.3	+1.0	June 7	39.5	+2.1
	45.3	+1.0	June 8	41.0	+1.5
	46.4	+1.1	June 9	42.0	+1.0
	47.7	+1.3	June 10	42.7	+ .7
	48.9	+1.2	June 11	43.1	+ .4
	49.7	+ .8	June 12	43.3	+ .2
	50.2	+ .5	June 13	43.4	+ .1
	50.5	+ .3	June 14	43.3	− .1
	50.6	+ .1			
	50.6	.0	1904.		
	50.6	.0	March 28	42.2	+1.6
	50.5	− .1	March 29	43.9	+1.7
	39.1	+1.5	March 30	45.6	+1.7
	40.7	+1.6	March 31	46.8	+1.2
	42.1	+1.4	April 1	47.6	+ .8
	43.2	+1.1	April 2	48.2	+ .6
	44.0	+ .8	April 3	48.7	+ .5
	44.5	+ .5	April 4	49.0	+ .3
	44.9	+ .4	April 5	49.1	+ .1
	45.1	+ .2	April 6	48.9	− .2

[a] Heavy rai

THE COLUMBIA RIVER.

By Mr. Edward A. Beals, *Portland, Oreg.*

DISCOVERY AND COMMERCIAL IMPORTANCE.

in 1792, or about eleven years after the Revolutionary war, l Vancouver was commissioned by the English to survey the, time, almost unknown coasts of Oregon and Washington. ngaged in this work he mistook the mouth of the Columbia r a bay, and so marked it on his chart. A few months later obert Gray, of the Boston trading ship *Columbia*, 83 feet long tons burden, fell in with Admiral Vancouver, who showed s chart. In the conversation that ensued Captain Gray d the opinion that the place the admiral had marked as a the mouth of a large river, but the admiral ridiculed this such a way as to greatly pique Captain Gray, and he deter- o verify his opinion at the first opportunity. The following from his log tells how well he succeeded:

> 1, 1792, 8 a. m., being a little to the windward of the entrance to the ore away, and in ENE., between the breakers, having from 5 to 7 of water. When we were over the bar we found this to be a large fresh water, up which we steered. Many canoes came alongside.

re indebted to this discovery for three of our largest States, as extensive parts of two others, although for many years after- he Columbia River continued almost wholly undisturbed by en, and it was not a very great while ago that William Cullen inspiringly wrote of it as follows:

> Or lose thyself in the continuous woods,
> Where rolls the Oregon, and hears no sound
> Save its own dashings.

All is now changed, and the dashings of many ships are heard u its limpid waters, which, including tributaries, are navagable for aggregate distance of over 1,000 miles. Portland, Oreg., the cl ing port for most of this commerce, was in 1900 the fifth port in United States in the export of wheat and flour, and the export that city for ten years ending December 31, 1900, amounted $72,634,079.

THE RIVER AND ITS BASIN.

The Columbia River rises in the southeastern part of British lumbia, in what is known as the Kootenay district; it flows north about 200 miles and, when just above the fifty-second parallel of tude, makes a sudden turn, runs south to the State of Washin and thence south and west through that State to the northern bo ary of Oregon, whence it flows westward to the Pacific Ocean, w its mouth is reached in latitude 46° 11′ N. Its length is estim to be 1,400 miles; its drainage area about 245,000 square miles; 200 miles above its mouth its discharge is 108,000 cubic feet second at low water and 1,600,000 cubic feet per second at high w Its principal tributaries are as follows:

The Snake River, rising in Yellowstone Park and emptying the Columbia River about 2 miles south of Pasco, Wash. Its le is about 900 miles; drainage area, 104,000 square miles; low-w discharge, 26,000 cubic feet per second, and high-water disch unknown.

The Willamette River, rising in the Calapooia Mountains in so ern Oregon and emptying into the Columbia River 12 miles n of Portland, Oreg. Its length is 150 miles; drainage area a 12,000 square miles; low-water discharge, 15,000 cubic feet per ond, and high-water discharge, 400,000 cubic feet per second.

The Okanagon River, having its source in British Columbia emptying into the Columbia River near Virginia City, W Length, drainage area, and discharge unknown.

The Spokane River, rising in the northern part of Idaho emptying into the Columbia River near Miles, Wash. It is miles long, and in 1902 its minimum discharge was 2,046 cubic per second and its maximum discharge 25,267 feet per second; d age area unknown.

The Pend Oreille River, which is a continuation of Clarks I rises in western Montana and empties into the Columbia Riv short distance above the international boundary line; drainage and discharge unknown.

The Kootenai River, which rises in southeastern British Co bia not far from the source of the Columbia itself. It flows s into Montana and Idaho, thence returns to British Columbia empties into the Columbia River about 35 miles north of the i national boundary line. Length, drainage area, and disch unknown.

Besides these tributaries there are many others, some of whic of considerable importance, such as the Deschutes, John Day, U tilla, Yakima, and Wenatchee rivers.

The eastern divide of the Columbia River drainage basin is summit of the Rocky Mountains from a point in Wyoming nea forty-third parallel of latitude extending north to the fifty- parallel in British Columbia. The river drains all of the U

States territory to the west of this line except a small part of southwestern Oregon and an equally small portion of northwestern Washington. The topography of this district is mostly mountainous, with many of the taller peaks capped with snow the year round. These mountains below the snow line are forested, while the uncultivated portions of the foothills and more level country in the interior of the basin are covered by bunch grass and the scanty vegetation peculiar to the subarid sections of the North American plains.

PRECIPITATION—DISTRIBUTION AND CHARACTER.

Within the drainage area of the Columbia River the variation in precipitation is greater than that of any other basin in the United States. Its distribution is governed by two laws, one being a general decrease from north to south, and the other an increase on the windward slopes of all hills and mountains. The heaviest rainfall is along the west slope of the Cascade Mountains. It is probably nearly as heavy on the east slope of the Coast Range of mountains, but we have no records to show the exact amount in this section. In the low valleys between these ranges the rainfall averages about 45 inches, while on the west slope of the Cascades, at Ashford, Wash., elevation 1,775 feet, it is 71 inches, and at Detroit, Oreg., elevation 1,542 feet (one year's record), 70 inches. At Government Camp, Oreg., elevation 3,580 feet, it is 94 inches, which leads to the belief that at an elevation of about 4,000 feet it exceeds 100 inches.

On the east slope of the Cascades we have only the record of Clealum, Wash., elevation 1,930 feet, with an annual rainfall of 29 inches. Higher up the precipitation must be greater, and probably amounts to about 50 inches. In the low sections of central Washington, central Oregon, and southern Idaho there are large areas having an annual precipitation of less than 10 inches, and from this amount it again increases in the Rocky Mountain districts to 15 or more inches, dependent upon latitude, height, and direction of slope. The following table shows the elevation, monthly and yearly precipitation, and amount of annual snowfall at the Weather Bureau stations within the drainage area of the upper Columbia River:

Monthly and annual precipitation (in inches), upper Columbia drainage area.

Station.	Elevation.[a]	January.	February.	March.	April.	May.	June.	July.
Baker City, Oreg	3,470	1.36	1.45	1.30	0.96	1.72	1.20	0.42
Boise, Idaho	2,739	2.31	1.60	1.82	1.15	1.63	.81	.19
Kalispell, Mont	2,965	.98	1.18	.89	.80	2.22	1.65	1.31
Lewiston, Idaho	657	.86	1.28	1.70	.82	1.47	1.18	.89
Pocatello, Idaho	4,488	.89	1.26	1.40	1.76	1.15	.42	.18
Spokane, Wash	1,943	2.39	1.96	1.38	1.27	1.45	1.49	.71
Walla Walla, Wash	1,000	2.17	1.62	1.86	1.78	1.66	1.13	.37

Station.	August.	September.	October.	November.	December.	Annual.	Average annual snowfall.
Baker City, Oreg	0.44	0.79	0.93	1.25	1.51	12.81	45.4
Boise, Idaho	.22	.43	1.01	1.30	1.95	14.42	24.5
Kalispell, Mont	1.09	1.97	.72	1.98	1.16	16.12	39.5
Lewiston, Idaho	.68	.99	.96	1.56	1.43	18.12	9.4
Pocatello, Idaho	.31	.28	.94	.90	.61	10.10	42.6
Spokane, Wash	.52	1.03	1.36	2.33	2.42	18.31	42.6
Walla Walla, Wash	.43	.97	1.50	2.17	2.07	17.73	24.2

[a] Feet.

Nearly a third of this rain falls during the three winter months, and very little occurs west of the foothills of the Rocky Mountains during midsummer. That which falls on the mountains in the winter is mostly snow, which drifts and packs in the gorges and canyons to great depths, although some of it is melted each winter by “ Chinook ” winds. These “ Chinook ” winds have many of the characteristics of well-known foehn winds common in the Alpine region of Europe, and they are of two kinds, viz, one which evaporates the snow without causing much run-off, while the other melts it without much evaporation, and consequently the run-off is large.

RIVER STAGES.

Records of river stages in the Columbia River system are meager and mostly of a fragmentary character. None has been kept for any great length of time on the upper stretches of either the main stream or its tributaries. The longest record is the one at Portland, Oreg., on the Willamette River, while the next longest is at Umatilla, Oreg., on the Columbia itself, about 300 miles from its mouth. Another good record is that of The Dalles, Oreg., which extends back to 1893. At this place the lowest water occurs the first week in February, the annual rise begins about the middle of March, and the crest of the flood arrives the second week in June, after which the water rather slowly subsides and the normal low-water stage is reached in September.

FLOODS.

The Columbia River never freezes throughout its entire length, and usually but a small portion becomes frozen at any one time. Therefore ice gorges are practically unknown, and the floods that occur are in the nature of annual rises due to the melting of snow in the mountains. The stages the river will reach each year depend more upon the rate at which the snow melts than upon the amount to be melted.

The danger line at The Dalles is 40 feet, and since 1862 the water has exceeded this mark 10 times. The highest water known was 59.6 feet, and occurred June 6, 1894. Other high stages were as follows:

	Feet.		Feet.
June 23, 1876	52.3	June 22, 1899	44.0
1862	48.9	June 18, 1903	43.0
July 22, 1880	48.7	June 22, 1896	42.9
June 14, 1882	48.2	May 24, 1897	42.7
June 19, 1887	48.1		

During the annual rise in the Columbia River the water backs up the Willamette River and causes floods at Portland, Oreg., which sometimes become high enough to cause serious loss to the business interests along the water front. Owing to these rises being backwater, there is no current, and they are less harmful than would be the case if the water ran swiftly.

The danger line at Portland is 15 feet, which is the stage at which the water begins to flood cellars and to cover the docks in the lower part of the city. The highest known water at Portland occurred

June 7, 1894, when the gage read 33 feet. Other stages above the nger line have been as follows:

	Feet.		Feet.
ne 24, 1876	28.2	June 19, 1898	20.7
y 1, 1880	27.3	June 9, 1879	20.5
ne 14, 1882	26.2	June 14, 1884	20.2
e 21, 1887	25.7	May 20, 1890	20.1
e 23, 1899	24.2	June 9, 1886	20.0
e 19, 1903	24.0	June 16, 1881	19.7
e 23, 1896	23.8	June 24, 1892	19.3
24, 1897	23.7	June 18, 1888	18.2
e 15, 1893	22.0	June 14, 1883	17.8
e 3, 1901	20.8	May 20, 1900	17.8
e 4, 1902	20.8	May 30, 1895	16.3
27, 1904	20.8		

n the last twenty-eight years the Willamette River at Portland been above the danger line from water backing up from the umbia River, 24 times.

he flood-warning service was established in 1895, and since then, ough eight floods have occurred, the damage wrought by them been small owing to the ample warnings issued.

ld settlers claim that in 1852 there was a moderate summer flood t judging from present landmarks, would have reached about feet on the Portland river gage, but back of this date practically hing is known regarding the annual rise in the Columbia River, ept what has been gathered from the Indians.

IE DIURNAL PERIODICITIES IN THE CLIMATE OF BALTIMORE.

By Dr. Oliver L. Fassig, *Baltimore, Md.*

or some years past the Baltimore observations of the United tes Weather Bureau have been in course of reduction and study the preparation of a report upon "The climate and weather of ltimore and vicinity." The portion dealing with climatic data ow in press and will probably be issued before the close of the r. In the present paper I have gathered together for preliminary lication some of the main facts regarding the diurnal march of e of the principal climatic factors. A fuller presentation of the ics contained in this paper will appear in the larger report reed to. The discussion of the hourly observations of the pressure, nperature, rainfall, sunshine, and wind direction is based upon en years' continuous record, and hence in each case involves the sideration of over 87,000 hourly instrumental readings. The recd of hourly wind velocities covers a period of twenty years, and the understorm record twenty-eight years. The hourly changes in the nount of cloudiness were determined from five years of direct obsertions at twelve stated hours of the day from 7 a. m. to 11 p. m.

Brief mention should be made at this point of one of the graphic ethods employed throughout this discussion. Some fifty years ago German investigator suggested the use of a method of presenting eriodic phenomena by means of a special kind of diagram, to which e gave the name of "isopleths," or lines of equal value. The method is particularly well adapted to a rapid survey of the hourly and easonal distribution of climatic elements and has been so applied occasionally in text-books and memoirs. In construction it resembles the maps prepared for showing the varying topography of an area. In place of the meridians of longitude and parallels of latitude to arrive at the geographic position of a given locality, we have vertical lines to represent the hours of the day and horizontal lines to indicate the months of the year, the intersection of these lines indicating the time sought. In place of the contour lines, or lines of equal elevation of the topographic map, we have lines connecting points of equal value of the factor under investigation, or "isopleths," projected upon the plane of the time lines. The rapid detection of the diurnal and annual distribution of the climatic elements is further facilitated in the diagrams by means of a system of shaded areas, increase in the intensity of the shade signifying higher values of the factor represented.

ATMOSPHERIC PRESSURE.

No decided evidence of a diurnal period is noticeable in the latitude of Baltimore in the barograph trace except, perhaps, during a quiet summer day, free from cyclonic disturbance. The irregular waves or cyclonic movements covering from two to five days completely mask the slight diurnal rise and fall of the barometer in the middle latitudes. The diurnal period, however, is clearly revealed in the average hourly values for even short periods; indeed, the experienced eye may detect the primary maximum and minimum on individual barograms at any season of the year. By combining hourly readings of the barometer for a long series of days the well-known double wave of the diurnal period is distinctly shown. Fig. 1 shows the phases as brought out by the average hourly values for a period of ten years for the months of January, April, July, and October and for the year. The primary or morning maximum of pressure occurs at Baltimore at about 9 a. m., local time, varying between 8.30 a. m in May and June and 10 a. m. in December. (See fig. 1.) The primary or afternoon minimum occurs at about 4 p. m. on the average varying from 3 p. m. in December, January, and February, to 5.30 p. m. in August. The average for individual months, of course varies greatly.[a] The secondary or night maximum occurs about 11 p. m., varying between 10 p. m. in November and December and 11.30 p. m. in April, May, July, and August. The secondary or morning minimum occurs at 3 a. m., local time, throughout the year except in January, February, and April. In January and February it occurs at 3.30 a. m. and in April at 2.30 a. m.

The most marked feature of the variation in the time of occurrence of the different phases is the gradual increase in the time interval between the primary maximum and primary minimum with the approach of summer, from five and a half hours in the winter months to eight and a half hours in May and June. The increasing interval is due mostly to variations in the time of occurrence of the primary minimum.

The amplitude of oscillation is not large, the greatest interval being about 0.07 of an inch, which occurs in March. The nocturnal amplitude is about one-seventh to one-ninth of the diurnal amplitude in the monthly curves. In the annual curve the ratio is 7 to 62, approximately one-ninth. The hourly distribution of pressure throughout the entire year is also clearly shown in fig. 2 by means of gradations in shading. The lighter shades of the central portion of the figure indicate the lower pressure of the early afternoon and early morning hours, while the heavier shades indicate the relatively high pressure

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[a] See Table III, Report on the Climate of Baltimore.

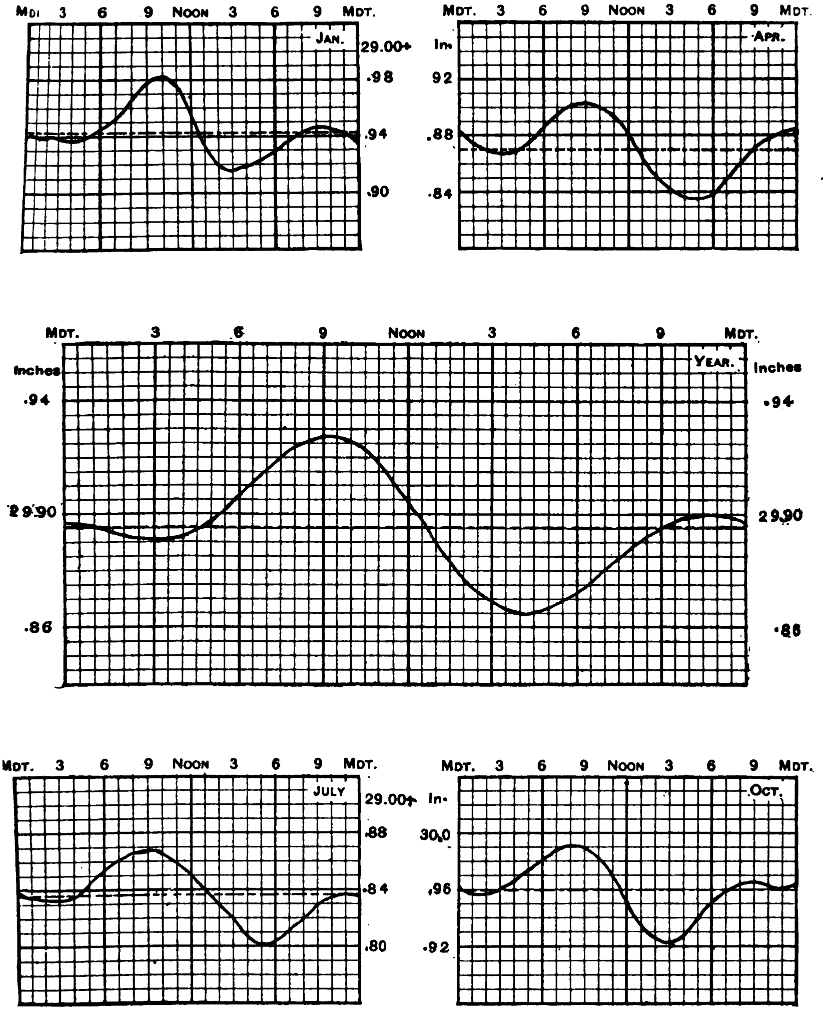

FIG. 1.—Average hourly barometric pressure.

f the fall and winter months and the late morning and evening hours. he lowest barometer (29.784 inches) occurs at about 5 p. m., local me, in the month of May; the highest (30.003 inches) at 10 a. m. in e month of December.

That the diurnal oscillation is not materially affected by the amount f cloudiness is clearly shown by fig. 3. In preparing this diagram xty clear days in *January* and February with a light wind were selected and thirty days in July. The hourly distribution of pressure was then charted for these days, in connection with a like number of cloudy days with a light wind for the same months, after eliminating the effect of cyclonic disturbances. The amplitude of oscillation is seen to be somewhat less on a cloudy day, but the form of the curve is similar throughout its extent, except in the winter months, when the deviation from the normal curve during the night and early morning hours is considerable.

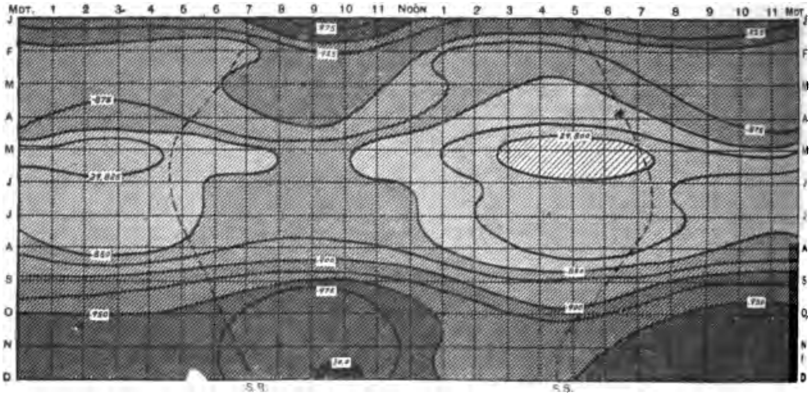

Fig. 2.—Isopleths of hourly pressure.

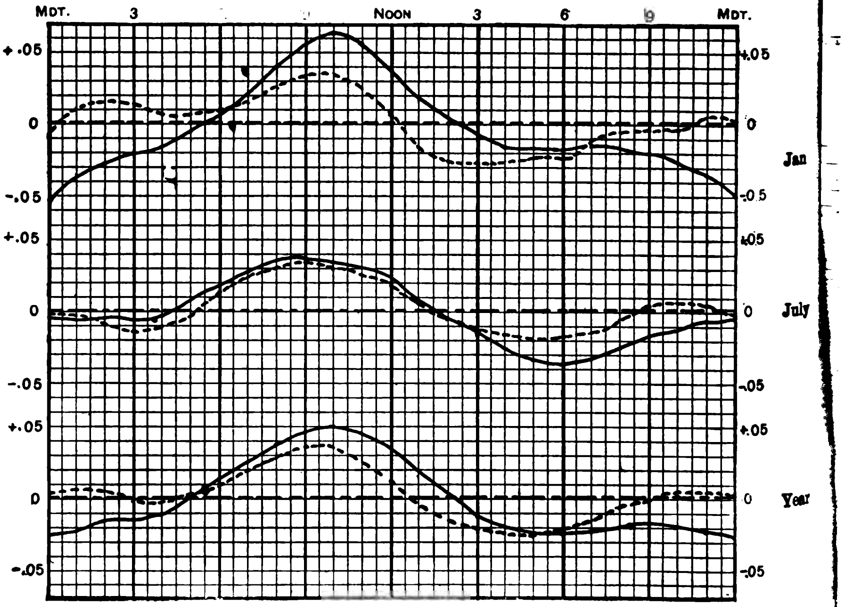

Fig. 3.—Hourly changes of pressure on clear and on cloudy days.
——— Clear days. ------ Cloudy days.

This diurnal movement of the barometer, while interesting when sidered locally, has a vastly greater significance when studied in nection with simultaneous changes in widely scattered points n the earth's surface. It is seen to be the local manifestation of ast atmospheric movement, probably cyclonic in its character, ch passes from east to west around the globe in twenty-four hours, which has its center under the heat equator. (See Chart I.) s phase of the diurnal variation of the barometer was brought in a paper read before the Milwaukee Convention in August, 1901. direction and amplitude at the center of this diurnal atmosric movement are shown in fig. 4.[a]

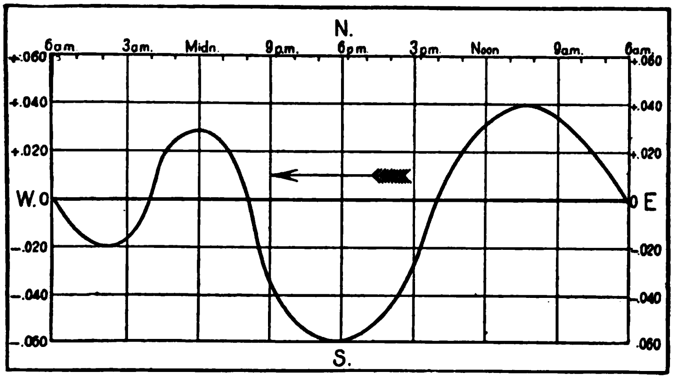

FIG. 4.—The diurnal barometric wave.
ıplitude of departure from the normal value for the day, in the center of the cyclone, near the Equator).

TEMPERATURE OF THE AIR.

he character of the diurnal variation of temperature is, of course, ch better known and understood. It is represented by a simple ve with its minimum point about sunrise and its maximum at ut 3 p. m. These facts are readily ascertained upon inspection of ost any thermograph sheet at any season of the year.

he normal curve.—The normal curves for January, April, July, l October and for the year are shown in fig. 5. The distribution temperature throughout the day and year is revealed in fig. 6. e lighter shades show the lower temperature of the winter and ly morning hours; the heavier shades the higher temperature of afternoon and summer hours. The time of sunrise and sunset is licated by the dotted lines passing vertically across the diagram.

In fig. 7 the rate of change in temperature from hour to hour oughout the day and night is shown. The heaviest shades indie the time of occurrence of the most rapid changes, the unshaded eas the time of least rapid change, while the heavy vertical lines rk the change from a falling to a rising temperature in the early rning, and from rising to falling in the afternoon.

Effect of clouds and rain.—In considering the diurnal variations temperature in the preceding paragraphs the character of the day s not taken into account. All days within the period of ten years were included. The amplitude of variation of temperature is m festly dependent upon the presence or absence of clouds. On a clo day the sun's rays are absorbed by the cloud mass and comparati little of the sun's heat reaches the earth's surface directly. To cover to what extent the normal variation is affected by the chara of the day, the diurnal variation of temperature was determined selected days in each season. For this purpose the days were grou as clear, cloudy, and rainy. Days were regarded as clear when

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[a] See Report of Milwaukee Convention, Bull. 31, U. S. Weather Bureau.

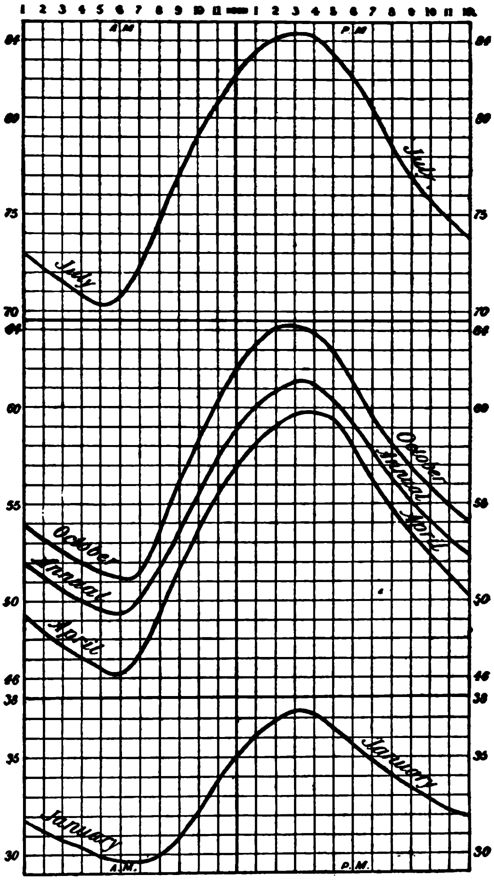


FIG. 5.—Average hourly temperature.

sunshine exceeded 90 per cent of the possible amount; cloudy w the sky was overcast the entire day; rainy when rain fell for m than four hours, not necessarily consecutive. Each group inclu approximately one hundred days selected from all seasons of the y A further restriction was imposed by excluding days with a mode or high wind. The results of the classification are shown in fig The amplitude, or difference between the lowest and highest t perature of the day, is manifestly greatest on a clear day, wit maximum value in the spring months. Cloudiness reduces the daily range of temperature to less than half that on a clear day. On a rainy day the difference between the maximum and minimum is reduced to 2° or 3°, equivalent to about one-fourth the range on a clear day in winter, and to about one-sixth the range in the spring, summer, and autumn. The principal phases of the diurnal march do not materially change in the summer and autumn months. The minimum occurs approximately at sunrise and the maximum in the early afternoon hours. There is a marked deviation, however, from the normal conditions on rainy days in autumn and winter. After ttaining a maximum for the day in these seasons it is maintained ntil nearly midnight.

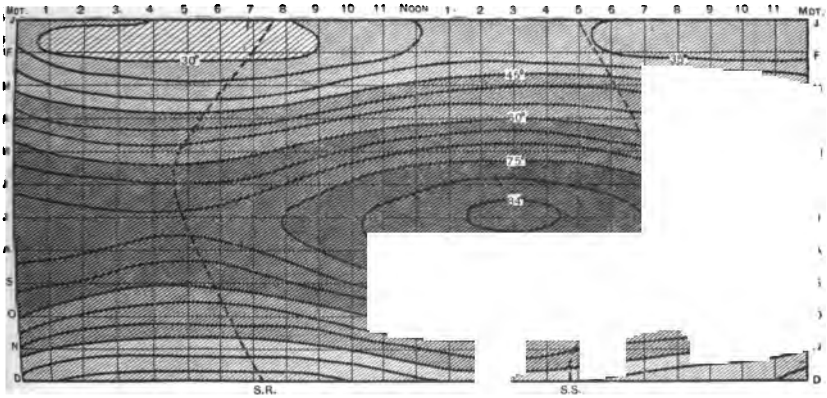


FIG. 6.—Isopleths of hourly temperature.

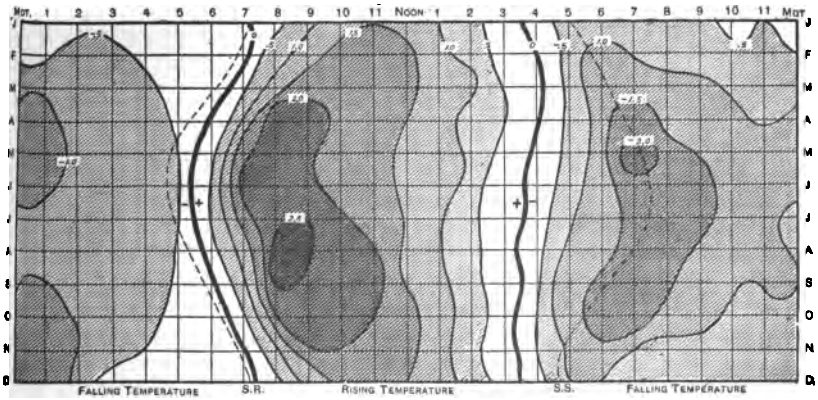


FIG. 7.—Isopleths of hourly rate of change in temperature.

One of the most interesting facts revealed in the diagram is the lative position of the curves for clear, cloudy, and rainy days in .e different seasons. In winter the clear day has a temperature cidedly below the normal for the season, while the cloudy and rainy days are well above the normal. In spring clear days have about th normal temperature, while cloudy days are far above the normal an rainy days decidedly below the normal. In summer the clear day i decidedly warmer than the average for the season; the cloudy da is about normal; the rainy day is much below the normal. I autumn the clear day is somewhat below the normal, the cloudy da about normal, and the rainy day well above the normal. These dif ferences in temperature, depending upon the amount of cloudine and precipitation, are sometimes very large. In spring the earl morning temperatures may be 10° to 15° lower with a clear tha with a cloudy sky. In autumn there is quite as marked a differenc

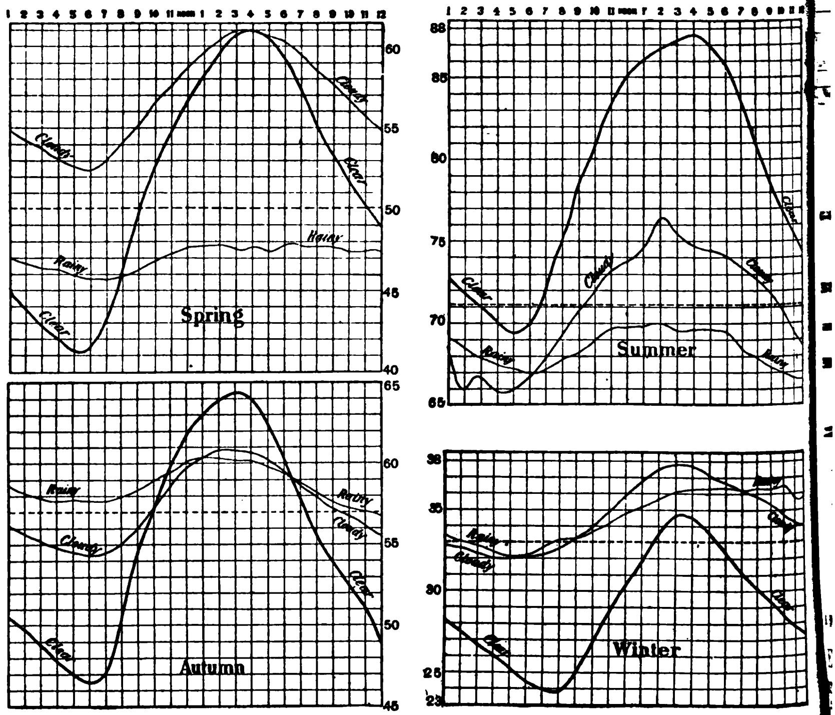


FIG. 8.—Effect of cloudiness and rain on the hourly temperature changes.

in the early morning hours. In the summer months the midday temperatures may be reduced 10° to 12° by an overcast sky and 15° to 20° by rain. In the autumn an overcast sky will maintain the average temperature of the day 6° to 8° above that of a clear day.

Effect of a snow covering.—To determine the effect of a snow covering upon the diurnal variation of the temperature, the average hourly temperatures were calculated for all days within a period of ten years upon which the ground was covered with snow to a depth of half an inch or more. A comparison of the resulting curve with that for the normal winter is shown in fig. 9. The two curves are identical in form and are parallel throughout their extent, but the days with snow on the ground show a temperature uniformly about

° below the normal temperature of the winter months. The temerature is lowered during the night by the intenser radiation from snow surface than from the uncovered ground. It is prevented om rising during the day because much of the heat of the sun, which ould otherwise go to heat the atmosphere, is spent in melting and porizing the snow. The air temperature is likewise affected by e snow preventing the communication of heat from the ground convection. As observations show that the difference between e normal hourly winter temperature and the hourly temperature er snow-covered ground is practically constant throughout the day d night, the daily range is neither increased nor decreased by the esence of snow. The low average temperature of the winter of '03-4 was doubtless due largely to the exceptional duration of a ow cover. The amount of snowfall in Baltimore was about normal, t a moderate depth of snow persisted during a period of time arly double the usual length.

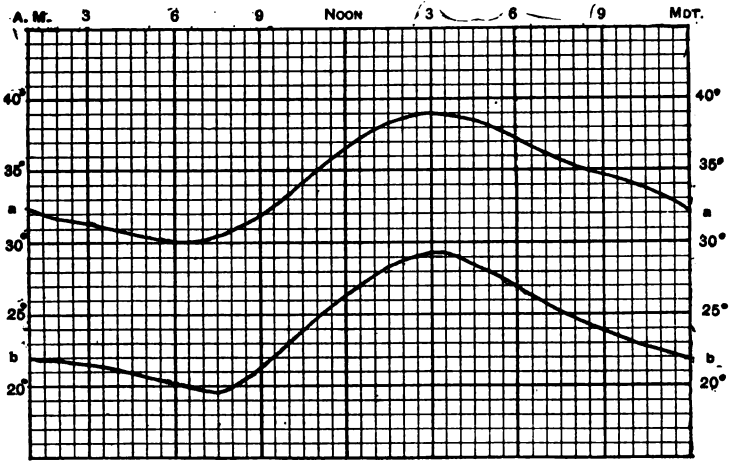


FIG. 9.—Effect of a snow cover upon hourly temperature changes.
(a) Normal winter temperature. (b) Temperature with snow on the ground.

Effect of wind velocity on temperature.—Another factor which rgely affects the diurnal range of the thermometer is the movement the atmosphere. It is well known that in a quiet atmosphere ere may be a considerable difference in temperature between the r resting on the earth's surface and that at a small distance above. the night and early morning hours of winter the thermometer may gister 5° or 10° lower near the ground than on the house tops. n a hot summer day the difference may be quite as large, but versed. In either case the lower layer of the atmosphere tends to ke on the temperature of the ground. Such differences are particurly noticeable in valleys and confined areas. They do not occur an active atmosphere. A breeze will quickly level any marked ifferences in the temperature of neighboring strata of air by interingling the lower and higher layers, resulting in an approximately niform temperature. The effect of wind movement on the diurnal ange may be clearly shown by classifying a large number of days ccording to total daily wind movement, days which in other respects ave approximately similar conditions. The results of such a classification are graphically shown in fig. 10. An equal number of clear, or approximately clear, days was selected in each of the months of

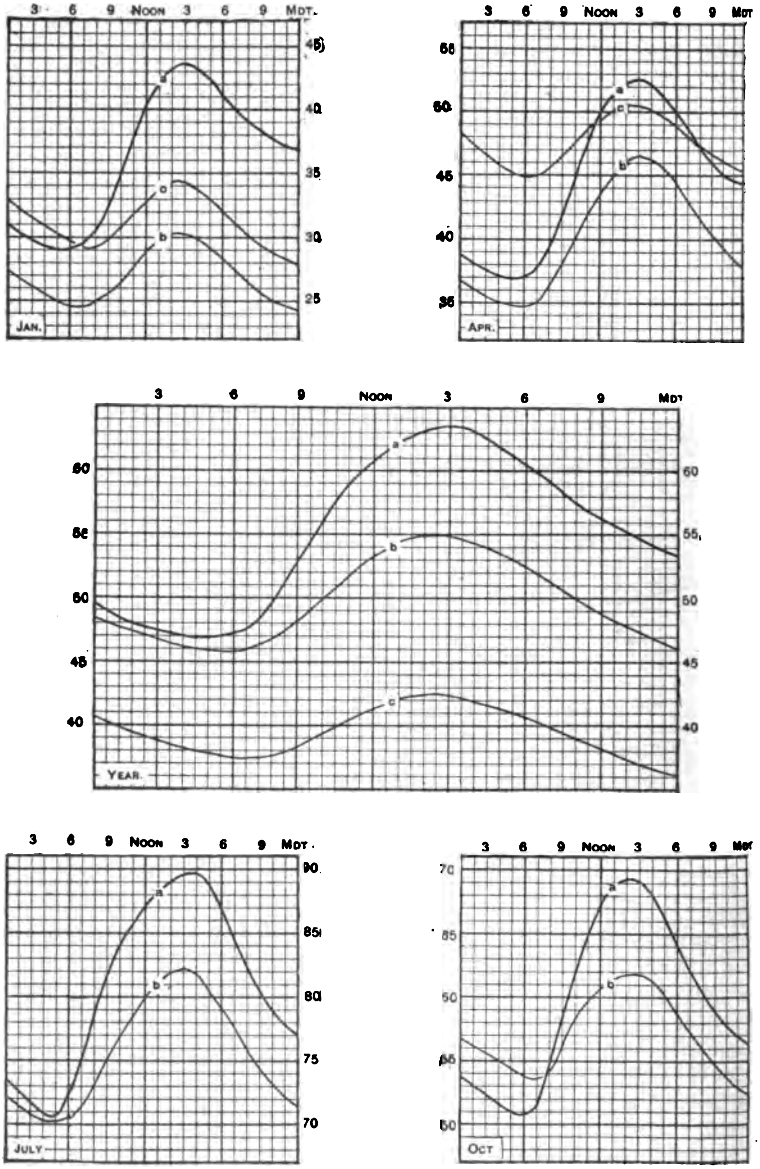


Fig. 10.—Effect of wind on temperature changes.
(a) Daily wind movement less than 100 miles.
(b) Daily wind movement 200–300 miles.
(c) Daily wind movement more than 400 miles.

January, March, July, and October. Those having a total wi movement of less than 100 miles per day were placed in one grou another contained days with a total wind movement between 200 a

00 miles; still another comprised winter and summer days with a ind movement exceeding 400 miles per day. The average hourly emperature was then determined for each group separately and a omparison made between the resulting temperatures. In each case he diurnal range of temperature is seen to be markedly lower with ncrease in wind movement, as shown by the following table:

Range of temperature on calm and on windy days.

Total daily wind movement.	January.	March.	July.	October.	Year.
	°	°	°	°	°
Less than 100 miles	14.6	15.4	19.5	18.9	16.8
From 200 to 300 miles	5.9	12.0	11.0	8.2	9.0
Over 400 miles[a]					5.4

[a] Winter, 5.2; summer, 5.7.

RELATION BETWEEN TEMPERATURE AND PRESSURE CHANGES.

In fig. 11 the curve representing the hourly pressure variations is shown in connection with the curve representing the hourly rate of change in temperature. The similarity in form of these two lines forcibly suggests an intimate causal relation between the two phenomena and serves to strengthen the theory advanced many years ago that the pressure changes are largely due to temperature changes at the earth's surface.

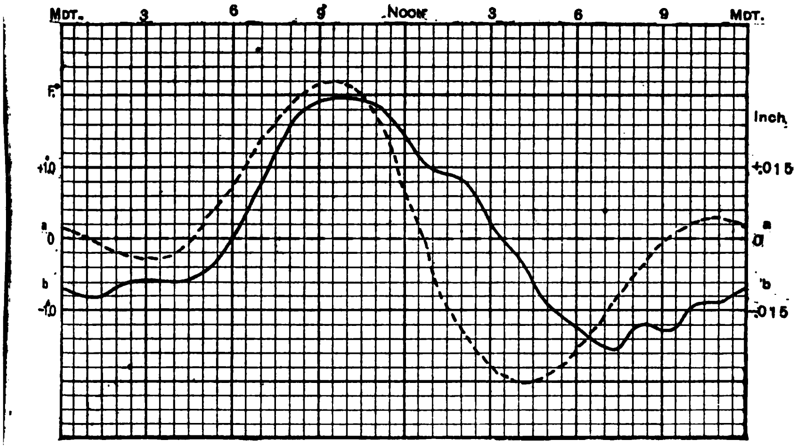


FIG. 11.—Relation between hourly pressure changes and the rate of change of temperature.
(a) Pressure curve -------- (b) Temperature change curve ————

RELATIVE HUMIDITY.

Continuous records of relative humidity are as yet comparatively are, the instrumental appliances for determining and recording this limatic factor being rather unsatisfactory. We have had at the altimore station for about two years a Richard hygrograph, the operty of the Maryland State Weather Service, which has given, on e whole, fairly satisfactory results, after carefully checking the midities *recorded against* the values obtained from direct readings of the wet and dry bulb thermometers at 8 a. m. and 8 p. m. The tw years' continuous record obtained by means of this instrument ha

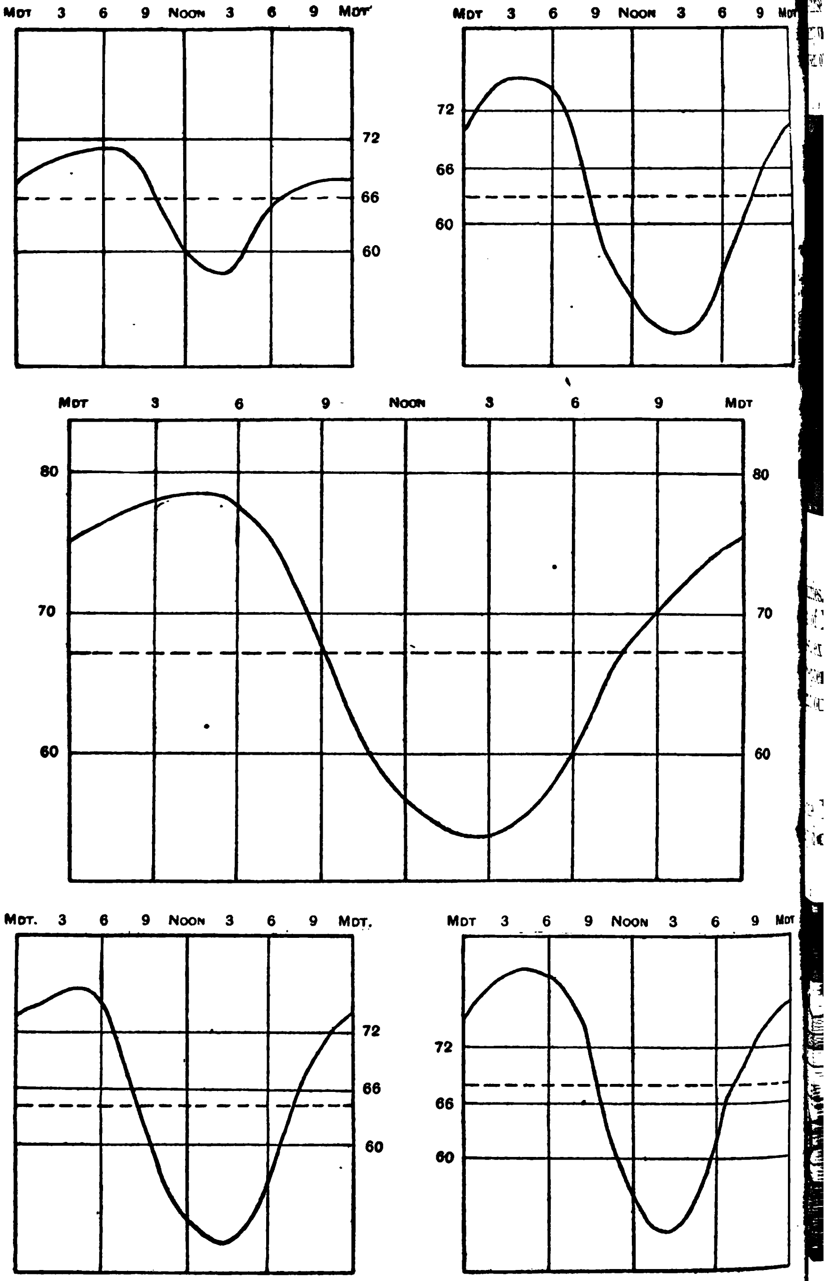


FIG. 12.—Hourly relative humidity (top, January and April; center, year; bottom, July and October).

been employed to obtain the curves of hourly variations shown in *fig. 12. In form* the curves resemble the temperature curves, showing a single maximum and a single minimum point. They are, how-r, exactly reversed as to phase, the maximum value occurring ut sunrise and the minimum between 2 p. m. and 3 p. m. In fig. 13 hourly values are shown for each month of the year by employing system of graphic representation already described. The lowest

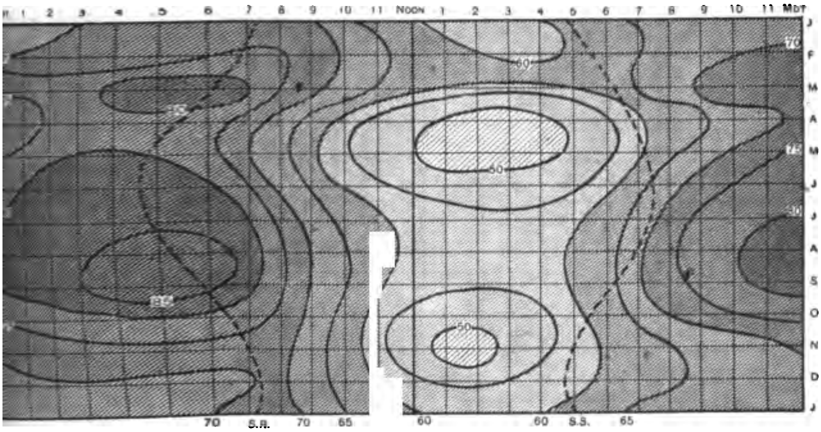


FIG. 13.—Isopleths of average hourly relative humidity.

midities, about 46 per cent, occur between 2 p. m. and 3 p. m. in the nth of May, and between 1 p. m. and 2 p. m. in November; the ghest, exceeding 85 per cent, occur from 4 a. m. to 6 a. m. in August d September. The details of the hourly distribution are clearly ought out by the lines and shaded areas of fig. 13.

PRECIPITATION.

In the latitude of Baltimore, where the weather conditions are so rgely dominated by the eastward drift of cyclonic disturbances, no

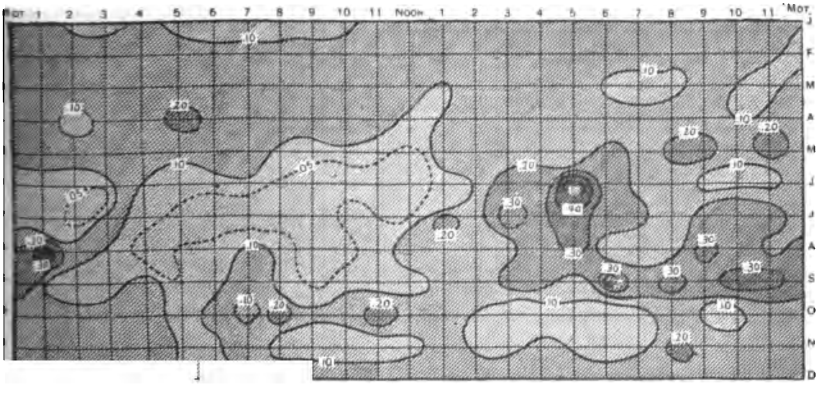


FIG. 14.—Isopleths of hourly amounts of rainfall.

ell-defined diurnal period was anticipated in reducing the hourly cords of precipitation. However, a close study of the diagrams will show evidence of a diurnal period, both in frequency and in th amount of the precipitation.

Amount of precipitation.—In the winter, spring, and fall month

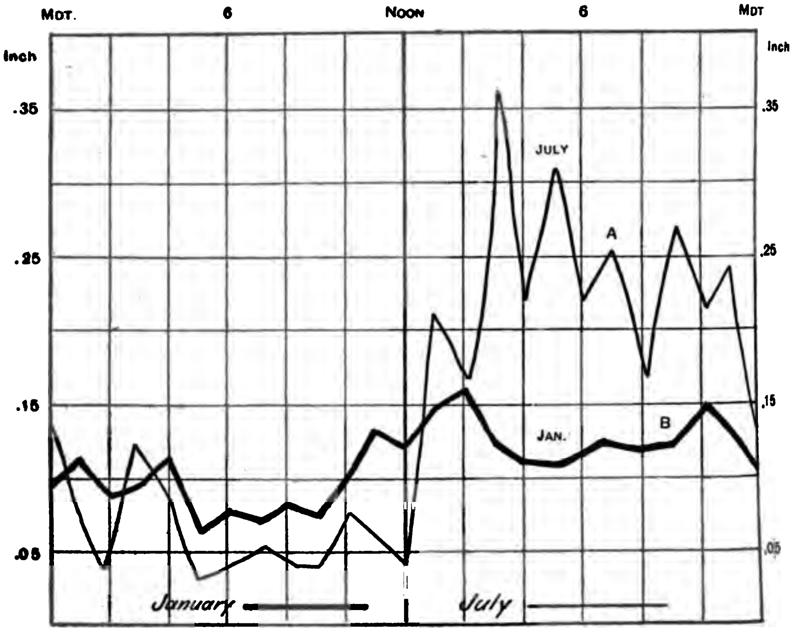


Fig. 15.—Total hourly amount of rainfall.

there is a very uniform distribution throughout the day in the amoun of precipitation. In the summer months, on the other hand, the effe of the heavy showers accompanying thunderstorms is clearly reveale

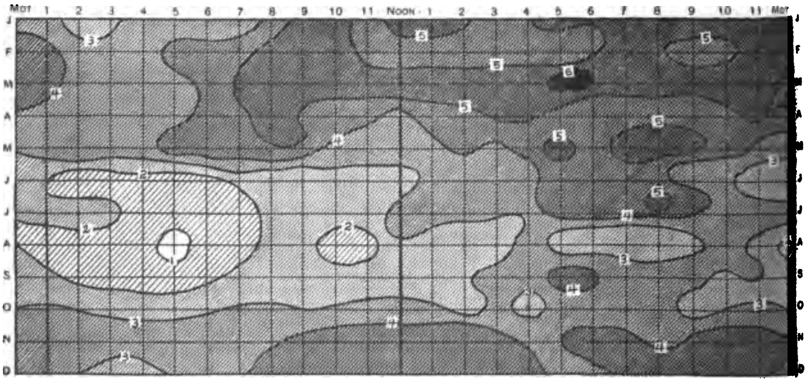
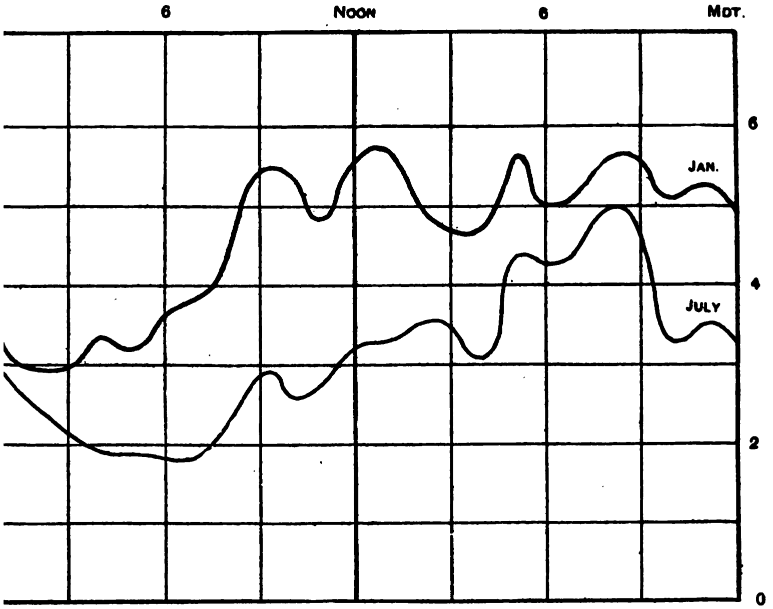


Fig. 16.—Isopleths of hourly rainfall frequency.

in the gradually increasing quantity of rainfall from the early morning hours to a maximum at about 5 p. m. This fact is clearly shown in fig. 14 by the gradations in the shaded areas. The numbers con-

1 with the curves indicate the average monthly amount of pre- .tion for each hour throughout the year. The same is shown ie months of January and July in fig. 15. The greatest average ıly amount of rainfall was recorded during the ten years from to 1902 at 5 p. m. in the month of June, namely, 0.50 inch; the amount, 0.03 inch, at 2 a. m. and 5 a. m. in the month of July.

:quency of precipitation.—In fig. 16 the total monthly fre- :y for each hour of the day and for each month for the ten from 1893 to 1902 is indicated by the curved lines and shaded , and in fig. 17 the frequency is shown for January and July



'IG. 17.—Average monthly frequqency of precipitation at each hour of the day.

ıeans of simple curves. The hours of least precipitation fre- :y are the early morning hours, from 1 a. m. to 5 a. m. in winter, g, and fall, and from 1 a. m. to 7 a. m. in June, July, and Au- The time of most frequent precipitation in the ten years from to 1902 was from 4 p. m. to 5 p. m. in the month of March, with 'erage of 6.1 per month. The time of least frequency was 5 a. m. : month of August, with an average frequency of 0.9.

CLOUDINESS AND SUNSHINE.

udiness.—The determination of the diurnal variation of cloudi- was based upon the reduction of a record of five years of eye vations at twelve stated hours from 7 a. m. to 11 p. m. The ; from 11 p. m. to 7 a. m. not being represented by observations ıltimore, the diurnal curve is necessarily incomplete. However, bservations for the remainder of the twenty-four hours are suffi- ly numerous to show the general form of the curve representing iurnal variation, and the curve may be completed by interpolating values for the early morning hours, without taking exceptional liberties. The result is shown in fig. 18. The diagram shows a simple curve with the maximum point between 1 p. m. and 2 p. m.,

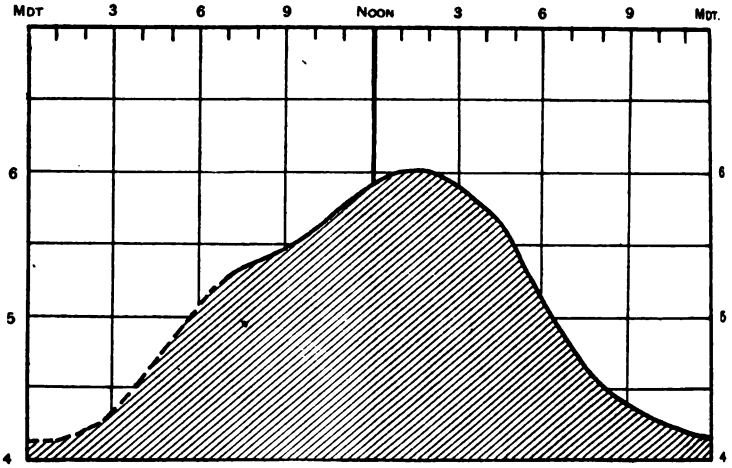


FIG. 18.—Average hourly cloudiness.

and the minimum about midnight or a little later. The increase is somewhat gradual, at least from sunrise to 1 p. m., after which there is a gradual decrease until 4 p. m., followed by a steady and

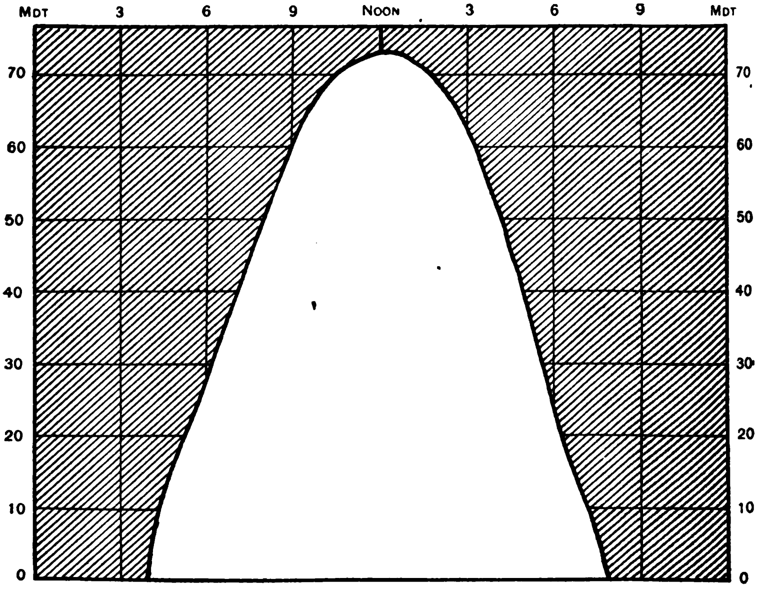


FIG. 19.—Average hourly sunshine.

rapid diminution to midnight. The average annual maximum about 6 and the minimum slightly above 4, on a scale of 10.

Sunshine.—The variations in the amount of sunshine from ho ιour were determined from a ten years' record of the thermometric shine recorder, a part of the Weather Bureau triple register. The ılts are shown in figs. 19 and 20. Fig. 19 shows the average diur- increase and decrease in the amount of sunshine for the year, ressed in terms of percentage of possible amounts. The curve cates a steady and rapid rise from sunrise to a maximum of 72 cent about noon, followed by a steady decrease to sunset. In fig. ι similar distribution is shown for all months of the year in a

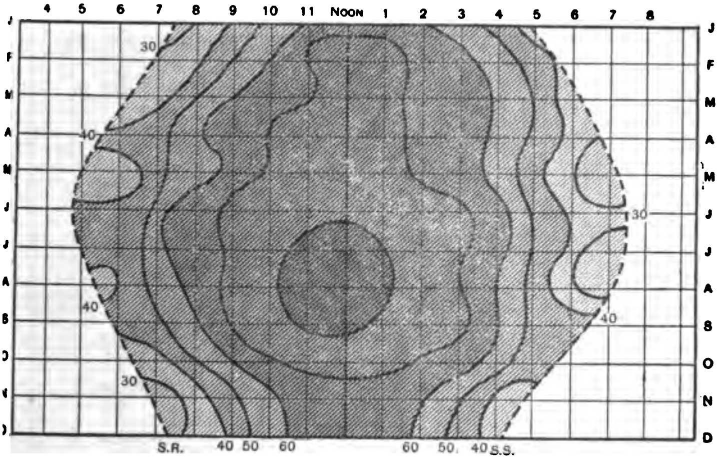


FIG. 20.—Isopleths of mean hourly sunshine.

ıer described in connection with the other climatic factors con- ɜd, viz, by means of isopleths of sunshine. Here, again, there ıniform increase from sunrise to noon or 1 p. m., followed by a ırm decrease to sunset, in all months of the year.

WIND VELOCITY.

e record of hourly wind velocities employed to determine the ıal variation covers a period of twenty years, from 1881 to 1900. e is a close uniformity throughout the year in the rate of change locity from hour to hour. During the night hours, from about m. to about 6 a. m., the winds are light and the range is small, ng from 4 to 6 miles per hour, according to the season. After se the increase is rapid until a maximum is attained at about ı. throughout the year. The minimum occurs at about 6 a. m. on verage for the year. The times of maximum rate of increase lecrease agree very closely with the times of maximum rate of ;e in temperature, namely, between 8 a. m. and 10 a. m., and en 6 p. m. and 8 p. m. The highest hourly velocities occur in h, reaching a maximum of 10 miles between 2 p. m. and 3 p. m. owest velocities (3.5 miles) occur from midnight to 3 a. m. in st. The maximum velocity is maintained for two to three ; then there is a rapid fall to 9 p. m., followed by a more gradll to sunrise. In fig. 21 the average hourly velocities for twenty years are shown for the months of January, April, July, and Octobe and for the year. In fig. 22 all of the months are represented b means of isopleths of wind velocity, as in preceding diagrams.

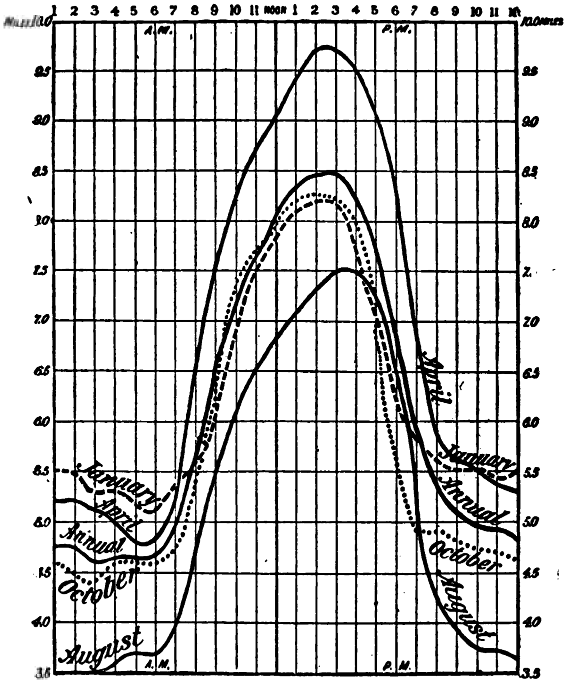


FIG. 21.—Hourly wind velocity.

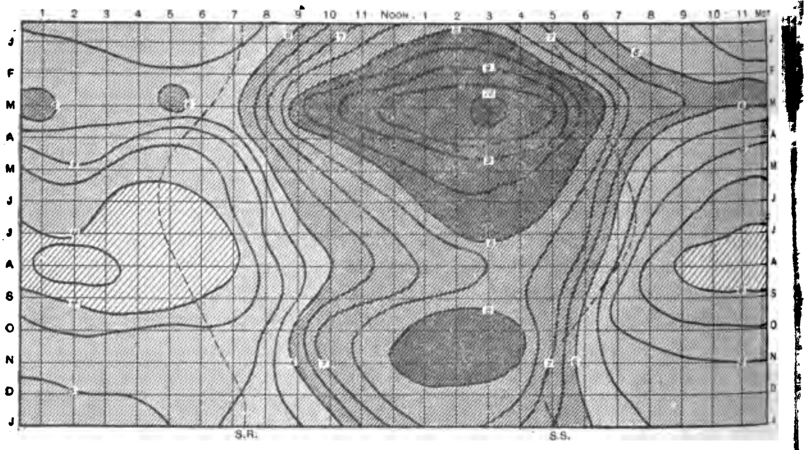


FIG. 22.—Isopleths of hourly wind velocity.

WIND DIRECTION.

One of the most interesting periodicities brought out by the study of the Baltimore hourly observations is that shown by the changes in

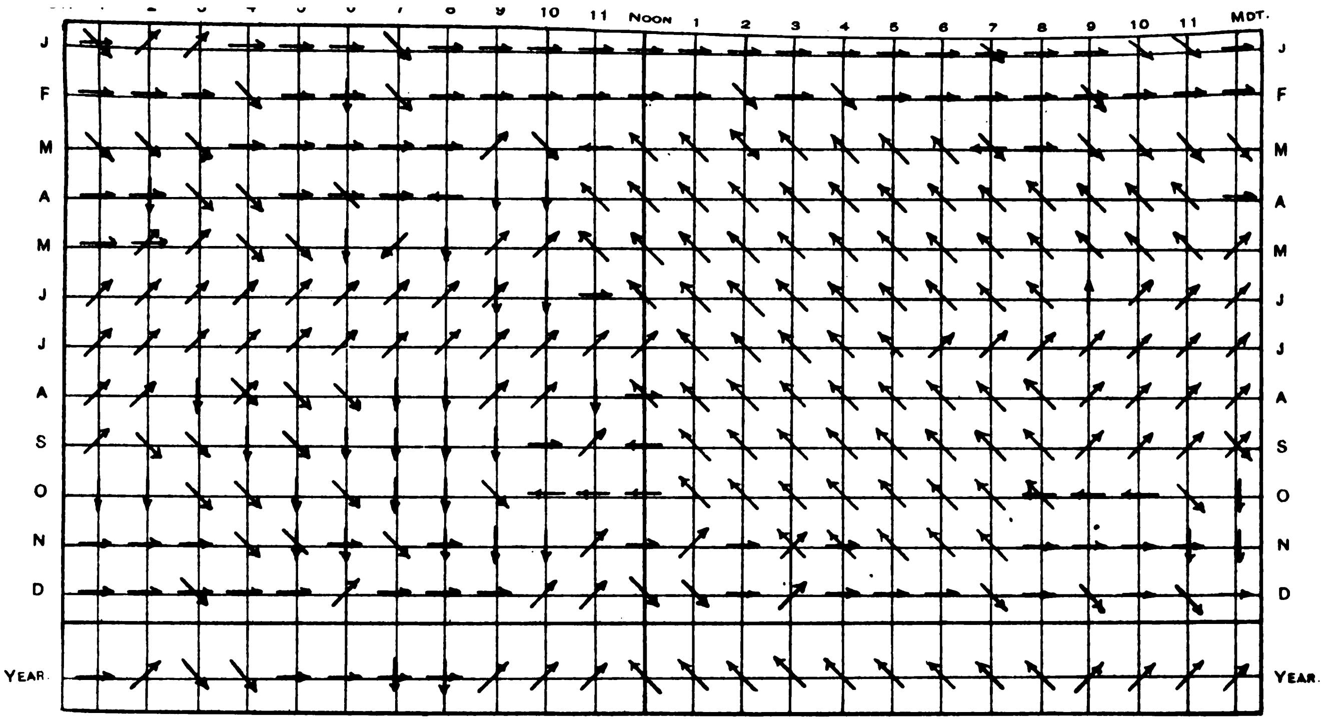


FIG. 23. PREVAILING HOURLY DIRECTION OF THE WIND.

EASTERLY WINDS IN RED; WESTERLY WINDS IN BLUE.

THE NORRIS PETERS CO. PHOTO LITHO., WASHINGTON D. C.

e direction of the wind from hour to hour. The prevailing hourly irections for ten years are shown in fig. 23. There is an abrupt ange in the direction from west or southwest to southeast from arch to October at about 11 a. m., and a return to southwest tween 9 p. m. and 10 p. m., except in June, when the return occurs early as 6 p. m. From 11 a. m. to about 9 p. m. the prevailing inds are steadily from the southeast, without exception during the onths named. The diurnal shift in the wind from west or southest to southeast, with little or no tarrying in the south, may be tected even in the winter months if the influence of cyclonic disrbances be eliminated. This has been done and the results shown fig. 24, in which each direction is given its true frequency of occurnce for January for selected days. A stated number of days was lected during which the total daily wind movement was under 100

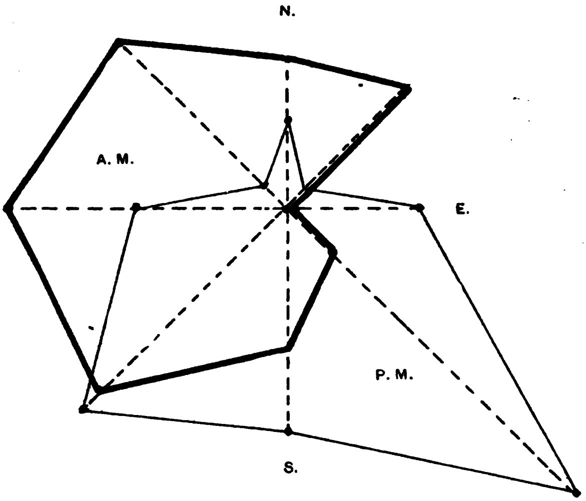


FIG. 24.—Relative frequency of a. m. (━━━) and p. m. (———) winds in January on quiet and clear days.

iles, and the sunshine ranged from 75 to 100 per cent. In other ords, clear days with a light wind were chosen in order to eliminate e effect of cyclonic disturbances. The winds of the morning hours idnight to noon) were then charted by means of a heavy line, and ose of the afternoon hours (noon to midnight) by a light line. n inspection of fig. 24 shows that a southeast wind prevails under ese conditions even in the winter month of January, though it is f course much more marked in the other seasons.

Is this diurnal change to be classed with the land and sea breezes? here is no body of water of any consequence within 15 miles of the tation. The phenomenon is less marked in June, when the land and ea breeze should be strong, than in October, when the difference in emperature between land and water surfaces, which gives rise to the ea breeze, is very small. Or is it to be referred to the diurnal yclone previously mentioned? The Baltimore hourly variations in irection of the wind do not contradict this supposition, but it requires large number of observations at widely scattered points to verify it.

It would be interesting to test this question further by mean
inland stations far removed from large bodies of water and
fluenced by considerable land elevations or other local condition

THUNDERSTORMS.

One more element deserves consideration in the discussion of
nal periodicities—the thunderstorm. It is a matter of common
rience that these occur most frequently in the afternoon hours.
it is, perhaps, not so generally realized how closely they are gr
about the hour of 4 p. m. in July. (See fig. 25.) The diagram
ing the frequency of occurrences of thunderstorms at Baltim
based upon all recorded instances during the period from 1
1903, or about 650 storms. As in the case of the precedin
grams, the figures are plotted upon a system of coordinates
senting hours of the day and months of the year, and lines of
frequency, or isopleths of thunderstorm frequency, are pro
upon the time lines. The lines of equal frequency are mark

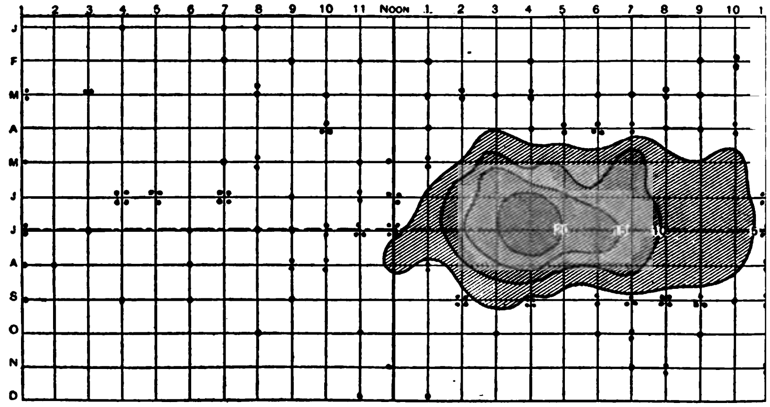


FIG. 25.—Isopleths of hourly distribution of thunderstorms. (Total numb
storms, 650.)

figures indicating the total number of storms recorded withi
entire period, while the distribution is further emphasized by
of shaded areas of varying intensity. The heaviest shade d
the greatest frequency. Over 100 out of a total of 650
occurred within the period of three hours from 2 p. m. to 5 p.
the months of June and July. The great bulk of all the
occurred from 1 p. m. to 10 p. m. in the months of May, June,
and August. The dots beyond the outer curved line of 5 occur
represent individual thunderstorms.

As to the direction from which thunderstorms move, ther
fairly uniform division between northwest, west, and southwe
the morning storms there is a slight preponderance in favor of
from the southwest; in the afternoon a greater percentage mov
northwest to southeast.

INSTRUCTION AND RESEARCH BY WEATHER BUREAU OFFICIALS.

By Prof. CLEVELAND ABBE, *Washington, D. C.*

In this address the author summarizes the growth of education n meteorology during the past thirty years within the Bureau or hrough its influence. He glances at the present condition of the sub-ect in Europe and this country and its future prospects. He shows hat progress in forecasting means not only education in the sciences llied to meteorology, but individual research. Finally, he shows hat research means, how it is to be fostered, and especially how it an be carried on at a well-equipped central meteorological observa-ory like that which is being built at Mount Weather, and the im-ortance of the subject to agriculture as well as to meteorology.

The present report covers a rather wide range and may be con-eniently divided into the following sections:

1. Historical sketch of the work of instruction in elementary mete-rology and advanced meteorology within the Weather Bureau.
2. Sketch of similar work by Weather Bureau officials lecturing n schools and colleges.
3. Sketch of the work done by graded schools, high schools, col-eges, and universities.
4. The need of still higher instruction and education, leading up o forecast work and research.
5. The possibility of carrying out a practical higher course at Washington and Mount Weather leading up to independent research ork.
6. The practicability of turning the attention of professors of athematics and physics in our universities and scientific schools to he needs of the Weather Bureau, so that they will present our prob-ems to their best students and prepare them for work in meteor-logy.
7. Research—what it means and how to attain it.
8. A course of training preparatory for research work, or a hand-ook for the use of students, leading through mathematical and ex-erimental physics up to meteorology.

INSTRUCTION BY WEATHER BUREAU OFFICIALS INSIDE THE WEATHER BUREAU.

From the very beginning of our meteorological work in 1870 it was ecessary for the Chief to organize and carry on a school of instruc-ion. In fact, instruction may be said to have begun in February, 870, immediately upon the passage of the law authorizing the organ-zation of the system of weather reports. The school of instruction was at the army signal post, Fort Whipple, Va., now Fort Myer, and was maintained until 1886, when abolished by order of Congress. At hat time both observers and higher officers were new to the work. At first the instruments, the methods of observation and report, and he telegraphic work had to be thoroughly mastered; then came the installation of stations and the establishment of proper relations with the commercial world. Telegraphic reports began November 1, 1870. For two or three months Prof. I. A. Lapham compiled daily maps and occasionally suggested to General Myer some public announcement of the presence and movement of storms. The regular tridail routine of maps, isobars, and detailed forecasts of the weather fo all parts of the country began after I joined the service, on Januar 3, 1871. But the tridaily work was too heavy for any one man Accordingly, a year later Lieutenant Craig was detached from th school of instruction and afterwards Lieutenant Dunwoody also, and both were assigned to study and practice along this line of work. In May, 1872, began the regular monthly alternation in forecast wor that has been kept up ever since. The room in which the forecast were made was from the beginning known as the "study room," bu in 1881 this name was transferred by Gen. W. B. Hazen to the ne and very important division of the office organized by me for meteor ological research as distinguished from forecast work. To this ne "study room" were appointed several young physicists, astronomer and mathematicians, under the title of "computers," whose name have become widely known. There was afterwards added to th "study room" Lieutenant Finley, with his assistants, for the stud of tornadoes, and again Mr. Sawyer, with his assistant, Dr. O. L Fassig, and others, for the preparation of the bibliography of meteor ology. Professor Ferrel and Professor Mendenhall held independen positions in the service. With reference to the instruction of th observers and officers, a number of special courses of lectures wer given to the classes at Fort Myer in 1881–1886, and Mr. Waldo wa assigned as instructor until his health was impaired by sunstroke. I my article on the work of the Signal Service, at page 238 of Weathe Bureau Bulletin 11, I have given some details with regard to th development of courses of instruction, as follows:

> Next to the instruction of the observer sergeants, General Myer's first anxiet was for the instruction of the army officers detailed to his service, and his ca in this regard was followed up by General Hazen, who also provided specificall for the instruction of the lieutenants in the Signal Corps, of whom four we appointed in 1881 and 1882 and others subsequently. This latter instructio began in 1882 with a course based on Deschanel's Physics and a wide range meteorological literature. It was subsequently enlarged from time to ti until in 1885–86 a class of six officers attended an extensive course of lectur and instruction (supplemented by monthly examinations) on the following su jects: (1, Abbe) The theory of instruments, chartography, general meteo ology, thermodynamics of the atmosphere; (2, Ferrel) theoretical meteorolog with but little mathematics; (3, Dunwoody) practical meteorology and weath predictions, topographic surveying and drawing; (4, Mendenhall) electricit and laboratory manipulation. The lectures thus delivered, especially those b Ferrel and myself, were in part embodied in subsequent publications of t Signal Office as appendices to the Annual Reports of 1882–1891.

But the influence of the Signal Service and Weather Bureau i meteorological instruction has been felt far outside of our ow ranks. Our earliest efforts were given to the introduction of th study of meteorology in the lower grade schools. The extensive co lection of self-recording apparatus exhibited since 1871 in the instr ment room of the office in Washington was one of the sights to be see by every visitor to the city and was very instructive. In fact, t success of our work during the first two years produced a profoun impression throughout the country, and everyone felt a little awe he looked over our weather maps and our apparatus, as though was in the presence of something uncanny. Every effort was ma through the daily press, and especially by Prof. T. B. Maury throu the popular monthly magazines, to educate the public to the idea th ur work was simply an application of principles that are well recog- ized in physics, and that indeed everyone ought to study the weather nap in his own interest. A small booklet was issued by the office ntitled “ Weather Maps and How to Use Them,” which had a wide irculation through several editions. At the close of the month of anuary, 1873, I submitted to General Myer a brief summary of the torms of that month under the somewhat ambitious title of the onthly Weather Review. Its publication was ordered, and has ntinued without interruption ever since. In fact, similar numbers r the six preceding months were afterwards prepared and pub- shed. This Monthly Weather Review has been greatly enlarged, nd its scope has broadened until it is now recognized as a very use- l educational journal in meteorology. The policy of the office has ways been to encourage the free distribution of the daily weather ap and of any information in its possession that will contribute an intelligent appreciation of the forces at work to bring about e complex phenomena of the weather.

As early as 1872 some of our stations began to receive visits from achers and scholars who were curious to know how the weather pre- ctions were made. In 1881 and 1882 I was able to show the prin- pal and the students of the normal school at Washington the acticability and desirability of introducing the first elements of eteorology as a branch of nature study in the lower grades of the iblic schools. This idea became widely disseminated. The simple rm of daily schoolroom record that we adopted was included in e Washington school exhibit at the New Orleans Exposition about 886. Something like it is now accepted wherever in this country y attention is given to nature study and meteorology. At the esent time more than 20 States and systems of public schools have troduced elementary studies of the weather maps into the lower ades and climatology into the normal and high schools.

Although in 1881 I was asked by Gen. W. B. Hazen to prepare a xt-book in meteorology, it always seemed to me that a text-book r the use of students could be properly prepared only after one had d long experience in the work of teaching and that any book that might prepare from my point of view would be unsatisfactory om the teacher's point of view; therefore the Weather Bureau has eatly stimulated all who have desired to prepare elementary text- oks; so that we now have books of every grade, from those of errel, Davis, and Waldo, down to the simpler works of Maury, e Conte, Tarr, Brigham, Gilbert, Dodge, and others who treat eteorology or climatology from the point of view of its applications geology, geography, plant life, hygiene, commercial activity, and en sociology.

The Bureau has thought it very important to stimulate as far as ossible the demand for information by specific classes of students of cience in our colleges and universities. To this end, in 1875 General Myer and in 1882 General Hazen, respectively, encouraged my notes nd periodical publications on the physics of the atmosphere, published under the title of “ Record of progress in meteorology ” in weekly and monthly periodicals, and partly collected in annual volumes either by Professor Baird personally or by the Smithsonian Institution officially. With these I may mention my translations of “Short memoirs on meteorological subjects ” in the Smithsonian Report, 1879, and a volume of translations entitled " The Mechanics the Earth's Atmosphere," in the Smithsonian Miscellaneous Col tions, 1891.

As an introduction to the study of instruments I prepared also " Meteorological apparatus and methods " (Ann. Rept. Chief Sig Officer, 1887, pt. 2), and finally my very incomplete " Preparat studies for deductive methods in weather predictions " (Ann. R Chief Signal Officer, 1889, pt. 2).

The most important work done by the Signal Service in its e to aid the higher studies of meteorologists was the stimulus and sistance given to Prof. William Ferrel, leading to the publicatio his Contributions to Meteorology, Parts I (1879), II (1881), (1883); his Distribution of Temperature (1884), and his R Advances (1885). These and other papers by him too numero mention, whether published by the Coast Survey before he ent the Weather Bureau in 1882 or published privately after he resi from the Service on his seventieth birthday in 1886, have given to discussions by meteorologists throughout the world and have tributed greatly toward precision in our ideas as to the mecha of the atmosphere. Ferrel's conclusions may be modified as knowledge increases, but he will always be recognized as the le in dynamic meteorology, an original thinker, an instructor in highest sense of the word. His work was always in close symp with observations. Such men as he must be encouraged; they be intrusted with the theoretical part of the work of research, as implies a rare knowledge of mathematics and the laws of cel mechanics and terrestrial physics, such as very few attain to.

During the past ten years the course of instruction at Harvar steadily developed. Prof. R. DeC. Ward has succeeded Prof. liam M. Davis and has published a translation of Hann's Clim ogy which is everywhere accepted as the standard text-book. I myself, with the assistance of the author, prepared a revised ed of Woeikoff's Climates of the Globe, as also a memoir on " Clin and Crops." Both of these large works are, I believe, worthy of p cation from their bearing on education and research. Of course contain many imperfections, but one must publish his best an others correct him. To do nothing and to publish nothing is sta tion and death. Even the Bibliography of Meteorology, whi started in 1874 and turned over to the Weather Bureau in 188 completion and publication, has as yet been only partially and in fectly published. I commend these three works to your ea attention, as I have always thought that these would be helpf all workers in meteorology in suggesting and carrying out va lines of instruction or study or research.

It is rather discouraging to work for years at one's best and find that the result can not be published. Doubtless some of you gone through this experience, but it must stimulate us to put work in better shape, so that it may not fail to secure the favo attention of higher authorities. It continually happens that the lisher who endeavors to estimate what financial return he may e for the publication of a given manuscript rejects that which world would like to have. There is no doubt but what the sa meteorological publications is so small that, except in the case o *mentary schoolbooks*, the publisher and the author or his fr nust bear the expense without expecting financial remuneration. On his account both European and American Governments, learned ocieties, and endowed institutions, like the Smithsonian and the Car- egie, have contributed freely to assist in the publication of the many reat works that have brought honor to the human race and have lvanced our knowledge to what we are pleased to call our present ate of civilization. Newton's Principia would never have seen the ght but for Edmund Halley, who provided the funds for its publi- tion by the Royal Society.

Our committee has requested each of us to give in detail the urses of lectures that we have delivered from time to time. I be- ve that my own work began in 1869 and 1870 in Cincinnati, with tures on the theories of Espy, Redfield, and Ferrel, and on the ather map. This was followed in 1871 by the first and third edi- ns of Weather Maps and How to Use Them. In 1882 I helped the ncipal in our Normal School in Washington, Miss Lucilla E. ith, to organize a system of simple observations and methods of dy for the use of the lower classes of the graded schools as a part he course in nature study. It met with favor and was continued n she was transferred to the training school for teachers in Brook- . In 1882 I also gave my first course of lectures at Fort Myer, plemented by those of Upton, Hazen, and Waldo, all of which published in the appendix to the Annual Report of the Chief nal Officer for 1882, and in 1885 my course before the lieutenants he Signal Service at the Central Office, in conjunction with the rses given by Professor Ferrel, Professor Mendenhall, and Lieu- nt Dunwoody. The same year I offered a course of forty lectures few students of Columbian University, now the George Washing- University, to which institution I had been appointed professor neteorology, but without salary as being a Government official. e that time this university course has been elaborated into a series ive courses, each occupying two or three lectures weekly for forty ks and covering the following subjects: (*a*) Elementary meteor- y and observation; (*b*) theory of instruments; (*c*) climatology; dynamic meteorology; (*e*) research. These lectures presuppose iderable knowledge of mathematics and physics. The last two ses are intended for postgraduate work only by those who wish to in the degree of doctor of philosophy with meteorology as the or subject. Of course very few persons have taken any of these ses, but among them we may recognize several active well-known . Undoubtedly only those deeply interested will find it profitable pend three hours a week on these studies, but such courses or r equivalents in the Weather Bureau should be kept up for the efit of the few students who may wish to attend them.

uring the past winter (1903–4) these lectures were combined with e given at the Weather Bureau in the editor's office and were le free to all who wished to attend. The course included a num- of the most interesting recent studies showing comparisons be- n the actual and the theoretical distribution of temperature, pres- , and air currents. Short courses of four lectures have also been n for several years to students of the Johns Hopkins University he mechanical and physical problems of the atmosphere.

y colleague, Professor Bigelow, has also interested himself in educational work along meteorological lines, and has given lectures parallel to mine to special students in the Columbian University.

The detailed list of my own lecture courses may be gathered from the annual reports of the Chief Signal Officer, 1881–1891; from various annual publications of Columbian University and the Johns Hopkins University, and from an article in Science relative to the introduction of meteorology into Columbia University, New York City, in 1893, and reprinted in the American Meteorological Journal for 1895.

II. INSTRUCTION BY WEATHER BUREAU OFFICIALS OUTSIDE THE WEATHER BUREAU IN SCHOOLS AND COLLEGES.

It is now about five years since we began to take pains to publish in the Monthly Weather Review short notes about the activity of our Service along educational lines. For nearly thirty years previously we had been urging that schools and colleges introduce meteorology into their curricula. This had been done in some cases, but it was becoming evident that the numerous higher officials of the Weather Bureau must take an active part in the crusade against ignorance, superstition, planetary meteorology, and popular folk lore if ever the work of the Weather Bureau is to be fully appreciated by the citizens of the Republic. Although no special orders were issued, yet the mere fact that we began to note in the Weather Review as a matter of news the instructions and lectures delivered by our men seemed to arouse great general interest, and I presume that during the current year some work along this line will be reported from every station, while at some stations it is becoming quite a prominent feature. There can be no doubt but that great good is being done and that every high school boy who listens to a lecture by one of our observers on the work done by the Weather Bureau, every one who sees the instruments and their exposures, the daily weather map, and the forecasts based thereon, receives thereby positive knowledge instead of indefinite or erroneous ideas, and immediately becames less liable to accept as science the miserable planetary meteorology so persistently advocated by many misguided teachers and newspapers. The extent to which astrology, superstition, and sun spot and planetary meteorology is accepted in this country would certainly amaze us if it could be stated fully. Perhaps it is fortunate that we know so little about it. But it will not do to shut our eyes to the fact of its existence any more than to the existence of gambling or drinking, fortune telling, or illiteracy. Probably 5 per cent of the voters of this country carry about them some little charm—a rabbit's foot or a horseshoe or a lucky penny—some reminder of the days when mankind trusted in good luck or the watchful care of some special fairy. The world has not wholly outgrown the superstitions of our ancestors. There are always some to whom mystery and luck seem natural, but to whom law seems uncongenial. But the lecturers of the Weather Bureau are always in a position to show that sunshine and rain, cold and heat, fair weather and stormy weather do not depend upon any occult or supernatural influence. The atmosphere and its phenomena are controlled by law—"natural laws," if you will—laws that are as simple and as inexorable as the law of gravity, *the law of the* expansion of bodies by heat, the law of inertia, the laws of reflection and refraction of light. Such simple laws as these, familiar to everyone in his everyday life, apply also to the atmosphere. We can not predict atmospheric motions and phenomena as accurately as the astronomer can predict an eclipse of the sun or moon, but that is because the astronomer's problems are comparatively simple—because they have finally been mastered by the studies and works of the thousands of astronomers and mathematicians who for thousands of years have labored on these problems since the days of the early Persians and Babylonians and Egyptians. The world had to work and wait two thousand years before Copernicus, Galileo, Kepler, and Newton opened up the way to our recent rapid progress. Meteorology may have to go through the same history, but there can be no doubt that the mere fact that we are to-day unable to make perfectly accurate long-range predictions of the weather for any given locality for a given period is no justification for relapsing into the belief that the problem is impossible, or for having recourse to the moon and planets, or augurs and haruspices, like the Greeks and Romans.

The progress of knowledge will eventually render it possible for man to overcome all the difficulties that now prevent the attainment of his ideals. The struggle for knowledge is a part of man's struggle for existence; the progress of science is the progress of the nation in everything that relates to its material and intellectual welfare. It is important and essential that as Weather Bureau officials we keep pace with the general progress of knowledge and make it felt in our lectures and instruction as well as in our daily work.

To this end the Chief of the Bureau and the Secretary of Agriculture are in hearty accord as to the general importance of maintaining some system by which the observers, the local and district forecasters, the section directors, and all other officials of the Weather Bureau may from time to time have an opportunity to become acquainted with the more important items that are being gradually added to our knowledge of the atmosphere, climatology, and physical or dynamic meteorology. Meteorology is a difficult subject if we study it from a university postgraduate point of view, but it may be made less difficult if we treat it as in undergraduate college courses, and it can be made very simple if we treat it as in the elementary courses for high schools or for popular public lectures. Of course it is the latter treatment that appeals to most of our lecturers and their audiences, but we hope that the universities and schools of science will give proper attention to the more difficult branches of the subject. In order that Weather Bureau men may have opportunity in their private reading or personal studies to keep pace with the best ideas in meteorology, our librarian publishes in the Monthly Weather Review the titles of all recent papers. He is also authorized to purchase and distribute to stations such works as Ward's translation of Hann's Climatology, and if anything else as good as that should be published, it will also probably be added to the station libraries. Undoubtedly a man may occasionally want something that the Service does not supply officially. Thus I have known of several who read French well enough to have warranted them in purchasing copies of Angot's Meteorology, which is based on his lectures at the National Agricultural Institute at Paris, and I hope that still others will read Hann's recent *Treatise on Meteorology*. Woeikoff has just published a treatise on meteorology that looks as though it would be exceedingly helpful and suggestive, but it is not in English, I regret to say.

Best of all, our Chief plans to have many of our own men, as fast a opportunity may offer, spend a few months in Washington, or possibly at Mount Weather, studying the meteorological problems, acquainting themselves with the work done in all the bureaus, divisions and offices of the Department of Agriculture, and making specia studies of climatological matters that interest the farmers of thei respective sections.

Whatever the Weather Bureau does for the intellectual improvement of its men, whatever the individuals do for their personal education, is sure to be recognizable in the steady improvement in ou daily work, including the public lectures for which the men becom responsible, and by so much do we increase the public appreciation o meteorology. As a public service we have undertaken a great wor a great public responsibility, somewhat in advance, it may be, of th average state of public sentiment and education; therefore, just a one who undertakes to pay a heavy debt puts forth every energy t accomplish the result, so we have to strive to the very uttermost t know, to learn, to do, and to say all that is wise and useful relativ to our beloved science.

III. INSTRUCTION IN METEOROLOGY BY COLLEGES AND SCIENTIFIC SCHOOL IN THE UNITED STATES.

When the Service began its work in 1870 there was a widesprea conviction that the weather is a matter too complex and difficult eve to be mastered by the intellect and energy of man. Under thi impression the majority of our countrymen were incredulous as to th possibility of weather forecasts. The establishment of the Burea was only possible by the help of a few far-seeing ones who believe that enough had been learned by such men as James P. Espy, Willia C. Redfield, Elias Loomis, and Joseph Henry to justify an attemp to put to practical use the knowledge and the opportunities offered b our extensive system of telegraph lines. From the beginning the wor of our Bureau has been pronounced an unqualified success. Ther are some who do not make use of it, but there are hundreds of thousands who do. But we must not rest satisfied. There is still grea room for progress. In order to attain this progress we must have men well versed in everything that bears upon the facts and theories of atmospheric phenomena. In order to get such men we must *make* them. They can only be made out of *students* in the severest sense of that word, students who devote themselves both to daily work along our lines and to the more abstruse study of difficult branches of science. One can not make a botanist, chemist, or astronomer, an electrician, or even a first-class farmer, without teaching him that theory and practice must go hand in hand. To be sure, some men will run all to theory; others will naturally run to practice. Some men love the life of the student, others prefer the outdoor work of practical business, commerce, or manufacturing. There are relatively few who can carry out such a combination of the two classes of work as we have to deal with. The universities of our country probably graduate 10,000 students annually. All of them are better off for their education, but only a small percentage have that desirable combination of high scientific knowledge, practical experience, and common sense that will enable them to become the leading meteorologists of the future. Unfortunately we at present fail to catch the attention of these 10,000 graduates, and therefore the prospect is that the development of meteorology and the improvement of Weather Bureau work may be seriously delayed, so that our science will lag behind many others. This condition of affairs must be remedied, if possible. We have begun to teach meteorology and to introduce the weather map in he public schools and the high schools as a part of physical geography, which is all very well as far as it goes. We must teach elementary climatology and meteorology in our colleges and universities. The fundamental knowledge of mechanics and physics is taught in most of our technical schools and schools of science; these fundamental principles apply to every branch of nature, including the atmosphere, but the courses of instruction dwell with great fullness n their applications to hydraulics, steam engineering, electrical ngineering, optics, and acoustics, and say little or nothing about their pplications to the atmosphere, the weather, the climate, and meteorology. Consequently our scientific graduates study everything else xcept the weather; they present instructive theses on subjects that have acquired interest to them personally, through the active efforts of their teachers, but that have no special interest to meteorologists.

The only remedy for this unsatisfactory state of affairs is to provide most explicitly for instruction in meteorology in our colleges nd universities. It need not be made obligatory, but must at least e offered as an elective in every institution. Only thus can we hope that out of 10,000 annual graduates perhaps 5 or 10 may be specially prepared to do the great work that is now required and in the future will be still more urgently required from the Weather Bureau. It is nconceivable that we shall go on gathering records, preparing maps f normal temperatures, pressures, winds, etc., statistics of floods and torms, maps of storm tracks, and volumes of upper atmospheric data without being required to condense all this knowledge into a comprehensive theory or a complete explanation of the facts and the easons why. Astronomers studied nature for a long time before a Place was able to compile his Mecanique Celeste, which contains the mechanical explanation of the movements of the celestial bodies o the minutest details. Nor would this have been accomplished so oon if astronomy had not been given a very prominent place in connection with every university and academy of science in the whole world. This collegiate recognition has secured for astronomers a host of students, and among these now and then one whose genius leads him to devote his life to the study. Thus it happens that stronomy has drawn to itself prominent and able men at all times. We may hope to do this in meteorology only when funds are provided or meteorological observatories, meteorological professors, and scholarships or fellowships for special meteorological students. There is eally a great need of such special chairs and buildings in order that he universities may give meteorology the attention that it deserves, nd it will not be improper for us individually to present the needs f our science to the public in every practicable way.

Our science must be taught not merely from text-books, nor yet om observations alone, but by experiment also. There is plenty of om for both experimental and theoretical work. In order to arrive

at precise results modern students have developed what is know
mathematical physics, in which mathematical theory and laborat
experiments and measurements go hand in hand. Sometimes
theory is in advance and experiments are made to test its accur
Sometimes the experiments and observations are in advance, a
theory must be devised to explain them and show their proper
tions to other facts that have long been known. Thus, for inst
Espy's theory as to the cooling of the air by expansion, leading t
formation of cloud and rain, has stimulated a long series of obs
tions on mountain tops and in balloons, and it is only very lately
the meteorological office at Berlin has announced that by mea
high ascensions of expansible balloons carrying up Assmann's
ration psychrometers, it has finally brought down records that
that adiabatic temperature gradients probably do exist in the
upper atmosphere very nearly as they do in the center of a cu
cloud or in the rapidly descending hot winds. However, obs
tion has also shown that radiation and conduction have an ap
able influence on temperature and motion, so that, what with eva
tion and condensation of moisture, rainfall and snowfall, an
original insolation, or, as Mr. Shaw calls it, "the solarization
have forces and phenomena in such complexity as to require
theory and experiment in order to understand them properly.

Of course we must not relinquish our efforts to respond t
demand for elementary courses, inasmuch as they are an integral
of the instruction in nearly all our normal schools and very ma
the high schools of the country. Probably twenty States hav
cially adopted as text-books the works of Davis, Tarr, Brigham
Gilbert, and are therefore committed to giving high school in
tion in elementary meteorology. Such courses are appropria
normal schools and smaller colleges, but larger colleges and uni
ties should do better; for these latter there should be provi
special work on the physics of the atmosphere and the special
ature of the subject. Several universities have privately indi
their desire to offer advanced courses of lectures similar to
given by Professor Bigelow and myself at Washington.

The number of students asking for complete, more advanced
more difficult postgraduate courses in universities is very small.
the number of normal school teachers asking for further know
corresponding to an advanced popular course in the six weeks'
mer session of many universities is very large. These latter s
be better provided for than they now are.

This demand for instruction is very imperfectly met. So f
the universities are concerned the true value of the subject, t
students and to the universities and to the country at large, i
appreciated. However, it may be thought that the demand ca
be fully met at present owing to the want of good teachers wh
qualified to give instruction.

The universities or colleges that take an active interest in c
tology and even make it prominent as a part of the courses in ge
phy or geology are: Harvard, Cambridge, Mass.; the Lawrence S
tific School, Cambridge, Mass.; Williams College, Williams
Mass.; the Massachusetts Institute of Technology, Boston, Mass
New Hampshire College, Durham, N. H.; the Ohio State Unive
Columbus, Ohio; the University of California, Berkeley, Cal.

lifornia Polytechnic School, San Luis Obispo, Cal.; Colorado Colge, Colorado Springs, Colo.; State Agricultural College, Fort llins, Colo.; University of Chicago, Chicago, Ill.; Columbian or orge Washington University, Washington, D. C.; Simpson College, lianola, Iowa (near Des Moines); University of Cincinnati, Cinnati, Ohio; State University of Iowa, Iowa City, Iowa; Yale Uniity, New Haven, Conn.; State College of Kentucky, Lexington, ; Bowdoin College, Brunswick, Me.; Johns Hopkins University, imore, Md.; University of Nebraska, Lincoln, Nebr.; Drury Col- Springfield, Mo.; Cornell University, Ithaca, N. Y.; Teachers' ege, Columbia University, New York, N. Y.; the University of iester, Rochester, N. Y.; Davidson College, Davidson, N. C.; the cultural and Mechanical College, West Raleigh, N. C.; Heidel- University, Tiffin, Ohio; Muskingum College, New Concord, ; Buchtel College, Akron, Ohio; College of Charleston, Charles- S. C.; State Agricultural College, Brookings, S. Dak.; State Unity, Vermilion, S. Dak.; the Northern State Normal and Indus- School, Aberdeen, S. Dak.; the University of Tennessee, Knox- Tenn.; University of Texas, Galveston, Tex.; University of iington, Seattle, Wash.; West Virginia University, Morgantown, a.; Lawrence University, Appleton, Wis.

addition to the above colleges and universities many normal ils, high schools and other establishments are enumerated in the cts from reports on this subject published for the use of this conon. Other universities should probably be included in the list.

all these institutions the courses of instruction include only vational and descriptive meteorology, weather forecasting, and itology. Little or nothing is said about the higher physical orology that is essential to the well-trained meteorologist, and h must be the foundation for any special improvement in daily long-range forecasts. These college courses bring one approxily to the same degree of knowledge that we expect our forers to have already attained to, and this, therefore, impresses till more with the conviction that at the present time the Weather au officials are not likely to be greatly benefited by attending of these college courses. Their only hope for higher education lie in their own efforts at private study and in the opportunities are about to be offered them at Mount Weather and at the Cen- Office.

an in a few minutes give you only a brief sketch of the studies ibjects that seem to me to be necessary for the education of the orologist—the ideal meteorologist; one who will be better than of us now is; the ideal man whom we hope to evolve from within own ranks by study at Mount Weather, or whom, perhaps, the ersities will educate for us when they take up meteorology in ppreciative way. Therefore my remarks will apply to courses istruction at any school of science, but especially our own at nt Weather.

repeat that it is important that whenever any official of the ther Bureau has an opportunity to teach meteorology in a college iiversity he should request that, if possible, facilities be afforded for something more advanced than popular lectures and texts, lantern slides, and the drawing of weather maps. It is not ult for one to acquire some skill in weather forecasting if he simply knows the weather map and the weather types that have accumulated for the past thirty years, but any considerable advance beyond that can I think, be acquired only after a more thorough study of the mechani cal aspects of our problems. Now, mechanics seems a simple wor because we know a little of the machines and mechanical problems o every-day life. But the mechanics of the earth's atmosphere involv the movements of gases, vapors, and liquids; the diurnal and annu variations of sunshine; the rotation of the earth; the influence radiation and conduction of heat, especially the influence of ocea continents, and mountains. If our problems are too complex to studied in detail with the help of the best modern mathematics, th may also be too complex to be studied in detail by laboratory expe mental methods. But let us not be discouraged; the present state b of experimental and of mathematical work is such that we shall greatly benefited by them. Both must necessarily be called in assist us in obtaining truer ideas of the relative importance of t respective factors in our problems. With their help we should able to analyze a complex situation into several simpler ones, ea of which may be studied experimentally; afterwards we may these parts together and study them as a whole. This is only the f damental principle of "divide and conquer" followed by Lagrang principle of the superposition of small movements or small forces.

An experimental laboratory for meteorological studies should clude a number of devices, such as an arrangement for studying a measuring in detail the movements of the air around a warm or c center; the effect of centrifugal force throwing the air toward equator; the formation and behavior of vortex rings; the cooling a warming of air by expansion and compression; the passage of m air through the dry, cloudy, rainy, hail, and snow stages; the effect mountains on the formation of cloud and rain.

These experimental studies should be preceded by the study of mathematical features of the same problems, so that one may kn how to interpret whatever he may observe.

Preliminary mathematical studies on atmospheric motions h been published by many authors, and excellent summaries of conc sions bearing on the general circulation of air are given by Profes Bigelow in his cloud report, his barometer report, and his articles the Monthly Weather Review. Many of you have read the abstra and preliminary summaries of these works that he has published the Monthly Weather Review. The mathematical knowledge quired in composing and in studying these papers is very considera and necessitates so many years of preliminary study that it is only to say that very few Weather Bureau officials expect ever to maste On the other hand, in each graduating class of a large univer there are usually several men that show special talent in mathem ical and physical studies, and it should be our aim to induce these at least some of them, to devote themselves to the mathematics physics of meteorology. Other sciences are profiting by the ste advances that are being made in these fundamental studies; why meteorology as well?

Similar remarks apply to the students who graduate from unive ties as specialists in experimental physics and the various bran of engineering, such as steam engineering, hydraulic engineer and electric engineering. They have become expert in all laborat manipulations and computations. They are familiar with many problems analogous to those that we meet with in the atmosphere and can certainly be of assistance in applying such knowledge to our own line of work. Some means should be found to draw them to us and not let them all go into the engineering professions merely because hese are more profitable than meteorology.

I conceive that our ends may be accomplished if only a few of our est colleges and universities will at least recognize, not to say introuce, the study of physical meteorology by undergraduates and postraduates. I am assured by some of our most prominent college prossors that they would gladly present meteorological problems to eir students if only we will tell them how to do it, and I have thereore prepared a long definite list of studies and problems for their se, which might be made a part of this report if it did not more operly form a separate "handbook" for general use.

Of course I know that graduate students of professional schools havg quite ordinary ability soon command better salaries than are paid our observers, while those of unusual ability in a few years command laries that are much higher than the highest that is paid in the eather Bureau Service. And yet these are the men whom we wish secure for the profession of meteorology. May not or must not me way be devised to make our Weather Bureau work and positions tractive to them? If this is not practicable, then possibly the iends of science may endow university positions sufficiently well to stify such young men in devoting themselves to the development of r science. These are the men that can carry on research with most pe of success.

When mathematicians have properly stated the problems of atmoseric motion, in the shape of what are known as differential equans, and have solved these equations—taking full account of the tual conditions as to boundary, evaporation, precipitation, temrature, sunshine, and time—then will be opened a new chapter in r science, and practical meteorologists will, like practical astronners, follow the footsteps of such mathematical leaders.

As illustrating the truth of what I have been saying as to the imrtance of mathematics, one need only turn to the papers published Ferrel; to those by Helmholtz, Margules, Rayleigh, and others, nslated in my Mechanics of the Earth's Atmosphere; or to that blished in the Monthly Weather Review, by Cottier, on the fundantal equations of motion; or to the memoir by Brillouin in the nals of the French meteorological office on Clouds Formed by Mixe; or to the excellent synopsis by the same author of many papers the general circulation of the atmosphere; or to the paper on old Riemann space recently prepared by Prof. James McMahon the St. Louis Congress of Mathematics, an early copy of ich I have had the privilege of examining. Our own Profes- Bigelow has published in the Monthly Weather Review some stracts of the results contained in his elaborate mathematical pers. Mr. Shaw, the chief of the meteorological office in London, also lately published some suggestive papers on the general circuion of the atmosphere, in which he shows what good results can be ained by a general course of reasoning, although one can scarcely ıbt but that mathematical analysis must have been used by him in attaining these results before he composed the paper in popular language, as printed in the Monthly Weather Review for June, 1904.

Mr. Shaw's idea is that the anticyclonic or high pressure areas over the Atlantic Ocean take less part in supplying air to the eastward-moving areas of low pressure than we usually think; that the motion of air in the middle latitudes is not so much a rotation around areas of high and low pressure as it is a fairly steady movement from the west, with temporary movements from the northwest or south. In fact, Mr. Shaw says:

> There is food for reflection in my analysis of the surface distribution of pressure into two sets of isobars running in opposite directions on similar lines. The monthly maps of the Weather Review showing pressure and temperature at the surface and pressure at the 10,000-foot level bear out my analysis to some extent. I have not gone into the details, but taking the maps for February there is a fall of pressure of 0.90 inch between California and Lake Superior at the 10,000-foot level with a trend similar to sea-level isotherms, whereas at sea level the isobars show a uniform pressure of 30 inches, except in the extreme northwest. So there must be a pretty stiff gradient in this lower air against the upper air gradient.

It is very encouraging to find that men of the highest attainments have thus begun to attack our problems from new points of view in mechanics. Every such new thought can but throw light upon the complexity of the problems and the sparseness of our knowledge of the true nature of the atmospheric processes with which we have to deal.

IV. THE NEED OF STILL HIGHER INSTRUCTION AS LEADING UP TO RESEARCH AND LONG-RANGE FORECASTS.

I repeat that progress in forecasting, which a few years ago meant merely a better acquaintance with the daily weather maps, now means not only this, but a deeper knowledge of all modern physics and of the present state of recent special meteorological researches and a personal ability in further research. The question is one of pure modern physics and of a knowledge of analytical mechanics that may be applied to meteorology, either by mechanical or numerical or empirical methods, or by the mathematical processes known as analytics, involving a great degree of familiarity with modern theories of differential equations and complex functions.

As illustrating this statement, I may first call your attention to what has been going on in India. The most important problem in that country is not the daily weather forecast, though this is imperative when hurricanes are at hand, but the long-range seasonal forecast of the duration and intensity of the monsoon rains, especially of the southwest monsoon, whose rains extend over June, July, August, and September. At Bombay the average date of the first fall of one one-hundredth of an inch of rain in one day is May 31, and the average date of the first day on which one-half inch of rain falls is June 6. The corresponding last date for one-half inch is October 2 and for one one-hundredth of an inch, October 12. The average duration is, therefore, in extreme, one hundred and thirty-five days, but for important rains only one hundred and nineteen days. We see, therefore, that the monsoon has quite definite limits for beginning and ending. But the dates themselves oscillate to and fro. The dates on which the first rainfall averages one-half inch daily extend from June 6 to

ugust 4, or sixty days, as shown by the smooth curve and figures on
ge 82 of Chambers's Meteorology of the Bombay Presidency.

The great droughts usually come in groups of two or three years
deficient rain. You will find the list of these and the attendant
portant famines given by Sir John Eliot in Bulletin 11, and
rinted in an article of mine in the Monthly Weather Bureau for
ember, 1901. The Indian meteorologists have laid a foundation
the study of these droughts by collecting data relative to the pre-
ng centuries. Normal conditions were determined so that we
d understand the special conditions as to pressure, wind, and
erature that attend the good seasons and the bad, for the crops
ndia depend almost wholly upon the heavy rains that come with
southwest monsoon, just as our own depend upon the rains or
's of specific seasons of the year. Finally, Sir John Eliot and
ssistants began to see that unusual snows on the mountains and
aus north of India meant light monsoon winds and rains; that
ual heat in the interior of Asia meant strong monsoon winds and
iful rain; further generalizations were made as to the relation
rometric pressure, and for many years they have been issuing
ficial seasonal forecast several months in advance. We under-
l that these have been very successful and useful until the last
drought seemed to go directly contrary to all their empirical
. After diligent search for a reasonable explanation and after
ing with lunar periods and sun-spot periods, Sir John rightly
to the conclusion that a broader, deeper knowledge of the funda-
al mechanics of our atmosphere was needed beyond that now
ssed by any meteorologist. The internal work of the atmosphere,
ts external relations, is the problem that must be better under-
l. As Sir John's own term of office was about to be closed by
etirement, he cast about for an available man as his successor,
who should possess eminent abilities in mathematical physics.
hoice fell upon Mr. Gilbert T. Walker, of Cambridge, England,
n many of you have seen during his visit to our central office
whose published researches had given abundant assurance of his
ty. Mr: Walker is now installed in Calcutta and Simla. The
rical method of forecasting will go on under Mr. Dallas until
Walker has developed some deductive method based on the
iples of hydrodynamics as a foundation stone; doubtless at first
ric rules will also enter into it, but eventually it will be largely
luctive system. Mr. Charles Chambers, director of the observa-
at Bombay, first published in 1878, in his Meteorology of Bom-
Presidency, an elementary physical and analytical study of some
res of Indian weather, especially of the rainfall. It is fair to
me that Mr. Walker will be able to go a step farther. India is,
fore, a case in which research began among the meteorological
ds of the past, from which empirical rules were obtained. Then
study was transferred to mathematical physics, in order to
in at least the elements of a logical deductive system. This
r of progress is precisely that followed by astronomy from most
nt times to the present, and, indeed, it must be the general course
rogress in every branch of knowledge. Astronomy happened to
he first to pass from the realm of empiricism to rationalism;
orology will soon follow.

Australia the most troublesome question is that of the recurrence of droughts, which are more terrible than any that are known elsewhere, even in India. A large part of Australia is under the influence of the southern tropical area of high pressure and descending winds. When it gets a general northeast wind corresponding to our southeast wind, it should have general rains over the vast interior basin if the land were all lowland; but the coast ranges of hills and mountains push the northeast winds upward, causing good rains on the coast, but leaving the winds to descend and grow drier as they penetrate the interior, thus exaggerating the relatively dry condition of that vast basin. A slight shifting of the general areas of high and low pressure may produce a change and give showers in the interior, but no one has yet been able to foresee the movements of these large tropical areas. During the nine years 1895–1903 Australia has suffered immensely both from general and from local drought. H. C. Russell, of Sydney, has maintained that there is a lunar period in these droughts; that the movements of the moon north and south attract the high-pressure areas, by virtue of which they move northward and southward, but if we consider the uncertainty of some of the rainfall data and the fact that sometimes the long-continued drought extends over all the variations in the lunar influence we shall perceive that the moon is not their cause. The droughts of India and Australia must be referred back to combinations of general movements in our own atmosphere.

Here in America, where a whole year is sometimes cold or warm, wet or dry, we also know how largely the total annual rainfall varies. The annual maps for a series of successive years differ from each other. Even the means of two or three or five years do not run along smoothly, so that it may be necessary to take an average of thirty years or more in order to attain satisfactory normal values. These irregularities in our climate must be attributed to the interactions of the general currents that constitute the circulation of the atmosphere as affected by the irregularities of the earth's surface.

We may get some idea of the problem before us by an experiment proper to a so-called geographical or meteorological laboratory; construct a relief model of the Northern and Southern hemispheres, respectively, upon what is called an equal surface polar projection; establish these disks upon the same vertical spindle, so that they may whirl around together, the Southern Hemisphere being below and the Northern above; let each model have a high edge representing the equator and pour in enough water to cover the mountain tops. If now the disks are rotated slowly, the water will be heaped up slightly at the equator against the rim, and if the rim is warmed and the polar regions cooled a general circulation from equator to poles will be set up. To be sure, this is a very crude substitute for our atmosphere, but still it does show us a circulation over a rough surface. If we introduce small floating bodies, particles of dirt, or drops of oil, or an upper atmosphere of oil or alcohol, we may study the irregularities introduced by the presence of the elevated continents and islands; eddies and overflows, swashes and calms, ascents and descents will appear in most unexpected places. At some points on the rim the water representing the atmosphere will be heaped up higher than at other points, and these heapings will change position from time to time as the currents change. The high water at any point on the rim of the

Northern Hemisphere will not coincide with high water at the corresponding point on the rim of the Southern Hemisphere, thereby showing us how the atmosphere may pass across the equator at one place from north to south, while at another point it is crossing from south to north. Now, into this complexity introduce a vertical rod and make a little whirl in the water. It will last but a minute and float along in the current. If it meets a continent or a mass of stagnant water it may move around it. Its course will suggest new perplexities, and we begin to realize how many combinations are possible in the real atmosphere, with its great areas of cloud and rain, of hot and cold air, and of storms. We shall perceive certain combinations of movements recurring at irregular intervals, and thus perceive that periods may exist in our atmosphere that are wholly internal, not kept up, caused, or forced by the action of the sun or moon, but due entirely to our own internal warm and cold currents, to the differences of the resistances of oceans and continents, and to the diurnal rotation of the earth on its axis.

We must not expect by any such mechanical method as this to ascertain the exact circulation and local currents of our atmosphere. The experiment does not imitate nature closely enough, but we begin to realize that analytical methods may possibly solve our problems when the experimental laboratory methods fail us. Both laboratory experiment and mathematical analysis will be needed; researches of both kinds are absolutely necessary to our progress.

In Russia meteorology has always been encouraged to a remarkable extent. The Government, through its Imperial Academy of Sciences, has always had at hand some of the most famous meteorologists of the world. Early in the nineteenth century Kaemtz was called from Halle, Germany, to the University of Dorpat. His treatise on meteorology in three volumes embraces all that was then (1820–1827) known of the subject. He began the publication of a Repertorium, which continued through three volumes and contained various important papers. At this same time in St. Petersburg Kupffer organized the central physical observatory and a grand system of magnetic and meteorological work throughout the Empire After his death Kaemtz was called to St. Petersburg, but he soon died (living only two years) and was succeeded by Wild, who was called from Zurich, and under whom physical and instrumental meteorology achieved its greatest progress. Twenty or thirty volumes, known as "Wild's Repertorium," enshrine a series of noble memoirs that must for a long time remain models of thoroughness. Under Wild's successor, Rykatchef, attention is now being especially paid to the upper atmosphere and to its dynamic problems. The meteorological service is distinct from the Imperial Geographic Society, which has given to meteorology three famous names—Wesseloffski, Thilo, and Woeikoff. Besides the central office in the city, there are maintained one model observatory just outside St. Petersburg, at Pavlosk, and a number of independent cooperating observatories, such as those at Tiflis and Irkutsk. The observatory at Pavlosk has worked upon several problems that will probably interest us in America, such as the measurement of the temperature and the moisture of the air, the velocity of the wind, the rate of evaporation from free surfaces in the open air, and the determination of temperature and pressure at high altitudes.

At Berlin, Von Bezold, the physicist, has taken a leading position in expounding the phenomena relative to the condensation of aqueous vapor in the atmosphere. Some of his writings will be found translated in my Mechanics of the Earth's Atmosphere. Under him Assmann and Berson have carried balloon exploration to its highest perfection.

At Paris Mascart has paid special attention to optical and electrical phenomena; Angot has given us a beautiful study on insolation and many climatological papers; Teisserenc de Bort has carried out that wonderful series of balloon and kite ascensions continued now for nearly fifteen years which has thrown a wholly new light on the condition of the air 5 or 10 miles above us, about which it now seems that formerly we knew nothing, but which is now become the most important question of the day. Perhaps the most interesting publications from the Paris office have been the various memoirs by Brillouin, bearing sometimes on the physics of the formation of clouds and at other times on the general circulation of the atmosphere.

In Vienna the most industrious and famous student of meteorology is to be found, Prof. Dr. Julius Hann, who has for forty years unceasingly sent forth a wonderful series of papers, some of them of large size, many of them shorter, but just as important. To him Americans owe the proper appreciation of the work of Espy and Ferrel. He has built a new structure upon their foundation and has gone beyond them. He combines observational meteorology and physical theory to a remarkable degree. To him we owe the magnificent Lehrbuch, an encyclopedic work on physical meteorology. It is well worth while to learn the German language in order to read this volume, since there is but a distant prospect of our ever having an English translation.

These are a few of the names of persons and institutions in Europe that have contributed by their researches to the advancement of meteorology. We have done well in this country; we can point to Meech, Ferrel, Cottier, and Bigelow in mathematical meteorology; to Coffin, Schott, Davis, and Ward in climatology; to Espy, Redfield, Henry, Loomis, Rotch, and Clayton in observational and inductive studies; but the number of our students is small as compared with that for Europe. We need not be discouraged if our output is comparatively small, provided it be sound and important.

But all this relates to postgraduate work, and I would first speak of preliminary undergraduate work. Instruction in meteorological research must be preceded by appropriate preparatory elementary instruction. We can not do postgraduate work until after the undergraduate work has been done. We must not think of struggling with nature's hardest problems when handicapped by imperfect knowledge and experience. The race is only to be won by the strong.

The didactic value of meteorology as a course in mental training is not greater than that of any other branch of science, but it is certainly to be ranked as equal to any other. It has, moreover, the advantage of dealing with problems that force themselves upon our attention daily, and in which we are personally interested as vividly and deeply as in any other relating to human affairs. It is a subject on which so many erroneous ideas prevail that it may be said that there is no other subject concerning which education is really more needed than meteorology. So far as mental discipline is concerned, it has not yet *been demonstrated* that any one subject, when properly taught, is more valuable than any other. The accurate observation of nature and the careful study of her laws are natural to everyone, but some wish to carry it much farther than others. The mind is developed, its ideas are broadened, the vocabulary is enlarged, the eye and the hand become accurate and useful in proportion as we observe and experiment in many difficult fields in order to answer the questions that naturally arise in every mind. When the child's spontaneous thirst for knowledge has been repressed by unnatural methods of education, we can correctly say that that method of education is not disciplinary. But the observational inductive method is highly disciplinary. The study of meteorology is also utilitarian. It disseminates correct ideas and nullifies the innumerable errors and superstitions that have come down to us from ancient times. If in addition to this it enables us actually to foresee better than we otherwise would the approaching changes in the weather, then its total value is not to be underestimated.

The commercial or pecuniary value of meteorology as a professional career will, we hope, steadily increase.

Among the subjects taught in the universities, such as the languages, history, mathematics, philosophy, and general science, there are many that fit the student for professional careers either as teacher, author, mechanician, chemist, electrician, engineer, or other useful trade, profession, or calling. It has been estimated that a thorough course in the sciences and the arts, such as is offered at the Massachusetts Institute of Technology, Columbia University of New York, Cornell, Harvard, Lehigh, Case, Rose Polytechnic, or other equivalent school of technology, will enable a man to acquire an annual salary or income of $3,000 within three years after graduation if he enters into active business or manufacturing. This is equivalent to the income from $50,000 at 6 per cent, and is therefore the same as though that amount of money were added to one's personal capital. He is worth more by so much than he would have been if he had not acquired this special technical knowledge. He has made more by four, five, or six years of study than he could have done in any ordinary business. This does not seem to be the case in respect to meteorology. Its pecuniary value to the individual expert is at present not great and will not be increased until there is a demand for specialists in this line of work corresponding to the demand for specialists in electricity, steam engineering, chemistry, architecture, and other branches of industry.

On the other hand, there is a growing demand for men who can make the most reliable weather forecasts. This is the practical part of meteorology and must continue to become of increasing importance year by year. Accurate daily forecasts are demanded. In proportion as this demand has been supplied in the past it has grown stronger. The conviction that good forecasts can be made makes an immediate demand for them, just as is the case with every other good thing that supplies a long-felt need. The invention of the telegraph, sewing machine, and typewriter was followed by immediate universal introduction and use. It is the unsatisfactory, imperfect machine or workmanship that is not wanted. Man wants the best if he is at all progressive. Just as fast as anyone can show that he has the ability to make good forecasts, just so soon will he find immediate and profitable employment, and especially by large business firms who are now every day losing thousands of dollars from their inability to foresee the approach of some disastrous change in the weather. Although the Weather Bureau is officially doing good work, yet better must be expected, and better can only be obtained by giving every possible stimulus and liberty to all to study and forecast to their heart's content. It is only by securing the cooperation of a great variety of talent that we can expect great improvement.

Even in those cases in which meteorology is not officially taught in the universities we may still, perhaps, induce the professors in physics, astronomy, and mathematics to turn the attention of their students toward special problems related to our work. This will be mutually beneficial. Consider the following examples:

(1) In astronomy it is very common to study the question of atmospheric refraction. Now the light that comes to us from a star is bent out of its course by the atmosphere in proportion to the gradual change of density of the different layers of air as the light descends from the upper strata to the earth's surface. This change in density depends primarily upon the change in temperature and pressure, and also slightly upon moisture and the components of the gaseous atmosphere. The astronomer is, therefore, largely dependent upon the meteorologist for his knowledge of the basis of this atmospheric refraction, which is a very important matter in all accurate astronomical work. For a hundred years astronomers have studied atmospheric refraction in a general way, assuming some simple laws for the vertical gradients of pressure and temperature, but the true condition of affairs is not expressed by such simple laws, and to attain accurate work the astronomers and the meteorologists must cooperate; not only must we investigate the average actual gradients of pressure and temperature, but we must know all of the details as to their variations from hour to hour and day to day. Now, the meteorologist may, by means of kites and balloons, study the lower portion of the atmosphere within 10 to 20 miles of sea level, but above these limits is an important part that can be reached only by optical methods and measurements that belong to physics. The meteorologist may ascertain the conditions that determine the exact amount of refraction produced by the lower atmosphere up to the greatest altitudes to which he can attain, but the physical astronomer must take up the work where he leaves off and study the higher atmosphere. Therefore it is that I say that students of astronomy in universities must have our important meteorological problems forced upon their attention if they would do the best work in their own profession. I may add that when studying astronomical refractions at Poulkova, in 1865, this same course of thought drove me from astronomy into meteorology as a correlated study, and I found both at Poulkova and at Washington astronomical observations that fully confirmed my conclusions as to a close connection between the conditions shown on the daily weather map and the irregular variations of refraction.

(2) As another illustration of the connection between our atmosphere and astronomical phenomena, I may mention the interesting hazy copper-colored light that spreads over the surface of the moon during a lunar eclipse. This colored light is sunlight that has penetrated the earth's atmosphere and passed on to the moon. The general condition of our atmosphere must decide as to the brilliancy and tint of the light that falls upon the moon. Sometimes we observe the silver white of the moon only slightly dimmed, at other

times it becomes a very dark red, showing that there has been an unusual amount of absorption of the upper end or short waves of the spectrum as the rays pass through our air. If the astronomer would keep an accurate record of all these changes in the aspect of the moon during total eclipses he would undoubtedly give us some basis for determining the condition of the earth's atmosphere, although only in a very general way. Accurate photometric observaions of the brightness of the moon during her total eclipses do, in act, throw some light upon the question as to whether there is a ydrogen atmosphere far above the oxygen and nitrogen of our ower air.

(3) Attending the beginning of totality in solar eclipses astronoters long since noticed peculiar bands of light and darkness moving apidly along the ground. They are particularly well visible as they ass over a white surface. These bands are sometimes known as wilow leaves, from their resemblance in shape, and it seems to have been early proven that they represent slender streams of warm air and old air mingling together in our lower atmosphere. These streams t like feeble lenses on the slender beam of sunlight that reaches the ound during the minutes preceding and succeeding the total phase the eclipse. The movements of these willow-leaf shadows are due incipally to the horizontal motions of the atmosphere, but sometimes e vertical motions modify these bands appreciably.

(4) The rapid movements going on in consequence of the mixture warm and cold streaks and the minute changes in density that acmpany condensation of vapor into haze and cloud produce another ass of astronomical phenomena known as twinkling or scintillation, virtue of which a star apparently oscillates in all directions about average position, and if it be low down near the horizon it underes rapid changes in color. The phenomena of scintillation can be udied in detail by some form of scintillometer. Even when the wer air is quite still, and there is no mixture of warm and cold eaks of air, it seems likely that the superposed moving strata may ve such wave motions as to produce twinkling; in fact, at the agstaff observatory, in Arizona, photographs have been taken of striated appearance that may possibly be due to the interference of e waves of light refracted and dispersed at the curved boundary faces, as well as of those that produce the ordinary twinkling.

(5) If we pass to the so-called physics of the atmosphere, we come on a large number of phenomena to which attention should be led in any course of instruction in general physics. It is desirable t students of physics have their attention especially directed ward problems that bear upon the atmosphere; those doing laboray work will find the following list of subjects and experiments eresting:

(6) The compression of the air in proportion to the pressure is wn by forcing mercury into a tube containing air; the pressure rted by the mercury is measured by the height of column required produce the pressure; when the height is zero we must consider t the air is already under a pressure equal to 30 inches of mercury; en the height is 15 inches the true pressure is that due to 30 inches s 15 inches. A series of measurements of pressures, temperatures, corresponding volumes should give us a confirmation of the well

known law of Boyle and Marriotte, and also a determination of the probable accuracy of our own work.

(7) According to the law of Charles, the volume of the atmosphere enlarges in direct proportion to its absolute temperature, or 273° plus the observed centigrade temperature. Laboratory experiments demonstrate this important law. Thus a straight glass tube, closed at one end, half full of air and containing a globule of mercuy as an index has but to be dipped into a vessel of hot water when at once you see the globule move as the effect of the expansion of the air within The expansion may be measured by the motion of the index.

(8) A very pretty series of experiments on the formation of clou may be made within a small glass case or box. By introducing laye of smoke into this box you may be able to produce phenomena anal gous to those that occur in nature on a large scale. An oblong ca 2 by 4 feet or 3 by 6 feet will suffice for a large number of exper ments. This was Vettin's method of study. Within this box hor zontal layers of different densities—i. e., hot and cold air, carbon oxide, oxygen, nitrogen, or hydrogen—may be produced. The mov ments of these layers when they and the box are tipped a little a very easily seen. By placing little obstacles on the floor of the gla case one may study the motions of the wind around mountains an ridges. By tipping the case up and down or rocking it to and f one may produce waves and seiches. By introducing warm tobacc smoke one may study ascending currents, and by using aqueous vap may even simulate the formation of clouds.

(9) When the wind blows strongly against any obstacle and i deflected by it, side currents are formed that may be exceeding important. Thus in trimming the sails of ships the navigator mu constantly bear in mind the mutual effect of one sail upon the othe The case of the wind blowing against a chimney top is one in whic we are all interested, as the "suction" or draft up the chimne depends upon the action of the chimney top on the wind. Man experiments were made on this subject by a committee of the Ame ican Academy of Arts and Sciences and by another committee of t Franklin Institute, both of whose reports are interesting and sho how the study of aerodynamics can be made useful to the world.

(10) Some students are especially apt to neglect the problems bear ing on the errors of the apparatus used by them, but the study o these is essential to accurate meteorology; an observer should under stand the nature and amount of every error to which his apparatu is liable in order that he may be on his guard against them. I have paid especial attention to this subject in my "Treatise on meteorological apparatus and methods," published as part 2 of the Annual Report of the Chief Signal Officer for 1887, and there is now much more to be said on the same subject. Of course the physicist will, as a primary duty, investigate the errors of his thermometers and barometers, but in addition to this the meteorologist is especially interested in the errors due to the exposure of his thermometer, the effect of the wind on temperature and pressure, the measurement of the motion, pressure or the velocity of the air, the movements of the upper air, the moisture and relative humidity of the air, the measurement of rain and snow, and similar questions.

(11) There are many interesting phenomena in nature that still *await complete* elucidation, such, for instance, as the formation of

ground ice, anchor ice, or frasil ice; the formation of ice columns in gravelly soil; the rôle of the dust that floats in the atmosphere; the problem of the origin and cause of the diurnal and semidiurnal variations of the barometer.

(12) The director of a physical laboratory may with perfect propriety turn the attention of his students toward meteorological apparatus and the meteorological uses of ordinary physical apparatus. Of recent years the measurement of the quantity of heat received from the sun, the determination of the polarization of the blue sky light, and the electric condition of the atmosphere have acquired increased interest and importance, and professional physicists may well encourage occasional students to turn in this latter direction rather than to devote an undue amount of time to electricity in its relation to engineering, telegraphy, and other ordinary practical applications. New fields of work are as attractive to the student of physics as they are to the geographer, botanist, or naturalist. The biological sciences are generally studied from a biological point of view, but they may also be studied as complex physical sciences. Elementary physics should be studied in the elementary and high schools in order to leave time and room for higher problems by the maturer student.

The preceding paragraphs merely illustrate the principle that the professional physicists of our universities must contribute to the education of the professional meteorologists. However, the proper prosecution of such works as those just mentioned implies not only a skillful experimentalist but the possession of some knowledge of mathematics. Therefore we have also to wish that the professors and special mathematical students interested in meteorology shall have their attention directed specifically to some of our problems; for instance, the mathematical expressions for the action of the wind on a plane surface, on a spherical surface, or on a hemispherical cup are as yet very little understood, and yet these laws enter into the theory of the anemometer. Problems in aerodynamics and hydrodynamics should be treated mathematically as well as by appropriate experiments with delicate apparatus. Measurements on a small scale give us data for determining a few fundamental constants that enter into theoretical formulas that may then be applied on a large scale. The latter formulas must be obtained before the experiments can properly be discussed. In the first stages of scientific work observations, hypotheses, and empirical formulas will suffice, but in a perfected science, theory comes first, namely, a deductive theory, based on the simple laws of nature, and observation comes in later in order to furnish material for determining the few fundamental constants. Such a mathematical theory is very much desired in anemometry, as it would contribute greatly to increase the accuracy of our results and allow of much extrapolation. Not only the theory of the anemometer, but that of the psychrometer is open to improvement at the present time, and this is also a problem in mathematical physics.

But there are still grander problems for the mathematicians of the universities. I refer to the motions of the atmosphere and the attendant temperature and rainfall. The motions of the earth's atmosphere are primarily the result of the action of terrestrial gravity and centrifugal force on an elastic gaseous atmosphere whose temperature and moisture are controlled by the action of the sun on the earth, the ocean, and the atmosphere. The interactions of the sun, the land, the ocean, and the atmosphere constitute a supremely difficult problem that can only be solved by the solution of the complex differential equations of motion of a gaseous mass moving over a rough sphere. The equations of motion have been written in several forms by different authorities and they will still bear revision, but this is the work of a profound student of pure mathematics. To him we must look to guide our thoughts in the right path and, perhaps, to invent processes that will contribute to the solution of the equations of motion. The courses of instruction in higher mathematics must be made to contribute to the education of the meteorologist.

It is only when a few of the many students in universities express the wish to learn more about meteorology that we can expect that a special instructor will be provided. For a long time to come we must be content with the attempt to recruit our ranks from among the general students of physics and mathematics. But have we a right to expect even this? Is there enough of salary or fame offered by our science to draw a man of highest ability toward us, even if he have a decided inborn interest in meteorology? The mechanical arts are all of them now requiring a much higher grade of education than formerly, and they get the men with the necessary education because they offer higher salaries and rapid promotions, or sources of greater income from business enterprises. No matter what the line of work may be, if it be congenial, and if a sufficient salary be offered, one may find the appropriate worker; vice versa, if an expert worker exists he may find a place to suit him on his own terms. Our aim should be to develop such workers; we naturally look for them among the students of mathematics and physics in our universities, and having found them we must make it to their advantage to pursue our meteorological studies. But while they are thus apparently getting a deeper insight into the mechanical problems of the atmosphere, the rest of us must keep on with our own mathematical studies in order that we may read and understand that which these may write. It will not do for us to let them do all the work; there is something for us to do also. They need an audience of appreciative readers and critics and we must be the audience. They need to keep their own line of study in close sympathy with the thought of the student of the daily weather map and the problems which it offers; we as students of the weather map can always help them in this respect.

V. THE POSSIBILITY OF CARRYING ON A COURSE OF HIGHER EDUCATION AT MOUNT WEATHER LEADING UP TO INDEPENDENT RESEARCH IN METEOROLOGY.

The preceding sections have shown us the character of the attainments that seem to be required in order that we may contribute most effectively to the progress of our knowledge of the atmosphere. We have been led to recognize the sort of men we need to carry on the proposed work at our Mount Weather observatory. This is to be the institution at which all the difficult problems in meteorology, instrumental, observational, mathematical, and theoretical, must be *successfully* attacked. Most of these will require many years for solution, but that, as I understand it, is precisely the object to be attained by the establishment of this research station. We have here a glorious site for the observation of thunderstorms; an outpost for the prediction of winter and summer storms; a location for high kite and balloon work; a high station for the study of formation of louds; a windy place for a study of anemometry; an isolated place or studying the dust in the free air. Observations of the heat of the un taken at the base and summit of the mountain will give us some dea of the absorption of solar heat by the atmosphere, in order to etermine in detail how the sun heats the air, and whether its power hanges from time to time. Our kite work will acquire increased alue by the establishment of this great central station; in fact the eventeen kite stations that we formerly occupied may yet be made to ive us important information. There are several forms of apparatus or the determination of the dew point that we may soon compare ith each other and with nature as a study in hygrometry.

Although the Mount Weather observatory is primarily for research ork, yet it must inevitably contribute generally to meteorological ducation. Those who are conducting special researches, those who re full of any one subject and thinking intensely about it as researchers must do, will certainly benefit us all if they stop for an hour nd tell us about the present condition of our knowledge on that subect, about the works that still need elucidation, or the correlated roblems that may be solved when the main question is settled. Our eteorological observatory on Mount Weather must in many respects esemble the famous similar observatories at Kew, Paris, Montsouris, amburg, St. Petersburg, Pavlosk, Berlin, Potsdam, Strassburg, ienna, Munich, Zurich, Mauritius, Manila, Zikawei, and Blue Hill. must correlate its work with theirs, and all these will welcome this ew addition to their galaxy.

It will be a privilege and an honor to carry on research without terruption at this beautiful location, but in planning for it we ust remember that research for the advancement of science is not work to be lightly undertaken. It is like laying siege to the enemy's ronghold. One can not foresee the many difficulties that stand in e way of success, and such study must not be undertaken with the dea of finishing it in a definite time or doing as much as possible and en stopping. There is no pleasure, no satisfaction, no praise in ork that is half done. A danger that is specially apt to be enuntered is that of undertaking to do too much at one time. There re many interesting questions that we would like to see solved uickly; but we must restrain our ardor and attempt only one thing a time. One thing well done is better than a dozen half done.

At the present time we especially need a comprehensive study of e daily weather map. Not merely a list of dates of typical maps, ut such studies as those of the men who, guided by their thorough owledge of mechanics, have analyzed weather phenomena from the echanical and physical point of view without confining themselves following pure analytical mathematics. They have combined neral ideas with observations in such a way as to give us better but rtainly not exhaustive ideas as to the processes going on in the mosphere.

One of the most important studies is that by Professor Langley d his assistant, Mr. Abbot. They have lately given us a series of excellent determinations of the coefficients of absorption by the atmosphere for rays of different wave lengths, from the upper end of the spectrum to the lower, invisible or infra-red; consequently, for the first time we seem to know something about the total absorption and, therefore, the total radiation from the sun.

A new examination of the radiation from a small unit mass of the earth's atmosphere has just been made by Prof. C. C. Hutchins Combining his figures with the studies of Maurer and Trabert w have thus made progress in our knowledge of the behavior of the fr heat in our atmosphere.

There is another equally important field that may not be calle research, but that bears closely upon it. We are beset with suggestions from many persons that the planets or the moon or other occul influences have a powerful influence on the weather. Statistics whe properly examined do not bear out these ideas, but, having becom once firmly ingrained in the popular mind, they will remain the until we can efface them by clearer evidence to the contrary. I dou not but that the students at Mount Weather will contribute thei quota to this gospel of education, and that it will become a brigh and shining light—an intellectual light-house—in a region whe superstitions and antiquated traditions are still considered to be qui respectable.

VI.—CAN EXISTING UNIVERSITY COURSES BE MODIFIED TO SUIT OUR NEED AND DEVELOP METEOROLOGISTS.

The universities that now give some recognition to meteorology c climatology and the correlated mathematical physics have alread been mentioned, so far as they are known to me. Most of the scientific schools mentioned in that list are located near Weather Burea stations; sometimes our station is in the college building. This i always the most desirable arrangement, since on the one hand th Weather Bureau official thus has convenient for daily use all his re ords and apparatus, and on the other hand he is within the stimula ing atmosphere of study and research. In no case does any un versity seem to have any special endowment or funds available f maintaining instruction and in no case do the fees from studen amount to anything appreciable in the way of maintaining a cour of meteorological instruction. As a general rule the fees for instru tion in any university do not cover one-third of the cost of maintaining the university. Education is given quite freely by our publi State and municipal institutions, and as for the endowed universities, they never charge enough to cover the actual cost. Some professors do, indeed, derive good incomes from fees, but they have th free use of the college buildings, libraries, and laboratories provided by the university and its friends; if these had to be paid for there would be very little left for the instructor.

With one exception meteorology is taught in these institutions incidentally to some other branch of learning. It is most frequently made a subdivision of geography or geology. In no case, as far as I am aware, does it stand alone, as it should do, as a branch of geophysics. Its association with geophysics is quite proper, since in this connection one may study it either as dynamics or as climatology; *but its subordination* to geography and geology quite belittles it and

ampers its development. Still the teachers of mathematics and
hysics are generally crowded with work, due to large classes of
tudents, and they hold out no encouragement as to the possibility
f their being able to add a special course in meteorology to those for
hich they are now responsible.

In general, when meteorology is considered as a subdivision of
ography or geology, the courses all relate to what may be called
ementary or descriptive science. A popular attempt is made in a
neral way to explain the causes of the observed phenomena, but the
act physical relations and dynamics are not presented in a way to
ake them at all numerically useful, or in a way that would enable
e to test thoroughly the accuracy of the views.

It will be noticed that of all the universities Columbian (now
eorge Washington Memorial) alone offers a complete systematic
urse covering all branches of meteorology and extending through
e four college years of undergraduate and the subsequent two or
ree years of postgraduate work. The heads of the other depart-
ents of instruction in the university have not failed to emphasize the
portance of our subject to the students of natural history, engineer-
g, and other branches of knowledge. But still we find it pushed
ide by other studies. It is considered as an elective, a major course
postgraduate work, but a minor in undergraduate work, except for
ose students who contemplate entering the Weather Bureau Service.

Experience has shown that teaching is best accomplished by a
mbination of text-books, lectures, notes and quizzes, recitations, and
boratory work. No subject can be thoroughly learned from text-
oks alone. We must elaborate the saying of Bacon and make it
ad: “Reading makes the full man; writing, the accurate man;
perimental laboratory work, the versatile, practical man; teaching
d lecturing, the ready man.”

In order to attain these educational desiderata, new treatises, text-
oks, and handbooks are sadly needed, especially one bearing on
paratus and methods, another on physical laboratory manipulation
d experimentation, a third on theoretical, physical, and mathemat-
al problems of the atmosphere. Professor Ward's translation of
ann's Climatology is a good general introduction to that subject.
ann's Lehrbuch is an encyclopedia, so far as observational meteor-
ogy, or the inductive branch of the subject is concerned. Woeikoff's
limates of the Globe is very suggestive, and his newest volume,
eteorology, in the Russian language, seems excellent from an instru-
ental point of view. But all these need still to be supplemented by
dditional treatises, for the subject is both broad and profound, and
anifold in its bearings on human life and activity, as well as on
very department of nature. There is really no subject on which
ore has been written, and it would be presumptuous to undertake to
ke account of it in one comprehensive review.

My belief is that by publishing a volume explaining meteorological
ethods and containing new problems for the use of those who are
pplying and testing their knowledge of mathematics, we shall make
easy for the young students of science to become interested in and
elpful to meteorology. Such a volume will not necessarily consti-
te a new college course, but will be, as it were, a special supplement
f problems additional to the present courses. No more time will be

required of the student, but he will be able to select his practical problems and exercises from a new field of knowledge.

VII. RESEARCH: WHAT IT MEANS AND HOW TO ATTAIN IT.

In some meteorological offices the work of research is committed to young men who are acquainted with the most recent progress in various branches of science and have, by their publications, shown themselves intellectually able really to advance our knowledge; in other cases the official research is done by older men. In both cases successful research implies such a knowledge of the subject and its literature as can only be attained by long-continued effort. Although many study the atmosphere and the weather maps, yet not all are properly fitted for research, and any office may consider itself fortunate when good research work is done by its employees and published promptly. Those who have good ideas are in duty bound to publish them for the benefit of the world, and if any such papers at present lie buried in our office files your editor would be glad to hear of them.

Research is a word that we are apt to use carelessly, as though anyone could "research." But this is not a matter to be spoken of lightly or executed in popular style. The various questions that now come before us as meteorologists must be acknowledged to be of the greatest difficulty; it is necessary that the student should master many preliminary problems before he can make any impression on ours. The mere fact that we are good observers or forecasters or popular writers will not help us at all. Research is a special branch of intellectual work that defies all ordinary business methods, but is governed by methods and principles that are entirely its own. Years are often spent in clearing up some doubtful point, and a century is not too long for several generations of scholars to labor on the perfecting of some apparatus, some argument, or some invention, or on the discovery of some law of nature that is at first imperfectly understood. Wherever research is made a regular business it must be managed by methods that encourage it, and must be relieved of influences that discourage or hamper the investigator.

In its beginnings meteorology was especially promoted by the learned societies of the world, and important memoirs will be found published in the transactions of such scientific societies as those of London, Paris, Berlin, St. Petersburg, Vienna, Boston, and Philadelphia, and in the Contributions of the Smithsonian Institution at Washington. But the necessity for special assistance from such sources has gradually diminished in consideration of the fact that every civilized nation now supports a special national or governmental office for the study of climatology and the issue of daily weather forecasts. Of course the preparation of weather forecasts implies the study of meteorology from a point of view very different from that adopted by those who study descriptive climatology, nosology, or hygienic atmospherology, or elementary nature study. These national weather bureaus necessarily support a high order of scientific students, and the best of them publish not merely daily maps and monthly or annual volumes of climatological data, but also special researches into the fundamental relations between the atmosphere, the earth, and the radiant solar heat. These researches are published either as a part of the archives or official publications of the institution, or through the agency of a learned society, or as appendices to the annual reports. Among the most remarkable series of memoirs of this character are those published by the meteorological offices at St. Petersburg, Paris, Berlin, Zurich, and London. The professional papers of the Signal Office and the bulletins and annual reports of the Weather Bureau correspond with these publications of our foreign colleagues. Our meteorological literature also includes the international publications relating to the polar expeditions of 1881–1883; the cloud work of 1896–97; the magnetic work of 1840–1850; and the numerous special governmental expeditions for the exploration of distant lands and oceans.

Research in meteorology can be pursued profitably by each and all of the following methods:

(1) Observational, as practiced since the most ancient times, but now especially assisted by the use of self-registering apparatus.

(2) Statistical, as in the branch of the study called climatology, wherein we determine averages or normal conditions as to variability, periodicity, changeability.

(3) Geographical, by the use of daily weather charts and generalizations drawn from them, as in our ordinary Weather Bureau work, for the purpose of forecasting.

(4) Explorational, by sending expeditions to the polar or other little-known regions, by using the balloon and kite, and by the occupation of mountain stations for the study of the upper atmosphere.

(5) Experimental, by the use of the apparatus and methods of the physical laboratory.

(6) Mathematical, by the study of the laws of thermodynamics, hydrodynamics, and aerodynamics, and the development of deductive theories as to the motions of the atmosphere that satisfy the laws of mechanics.

All of these methods must be recognized and encouraged in research work; each will contribute essentially to rapid progress; each of them throws light on the other and assists toward the general result; each demands some special ability or genius on the part of the man who undertakes work in that line. The fourth (exploration) and fifth (experiment) respectively require large expenditures for transportation and apparatus, and one must wait a long time before having much to show for the expenditure. The sixth or last (mathematics) is perhaps the cheapest as to outfit, but is also the most difficult intellectually, and there are very few who have the mathematical training or the genius needed to carry out this style of work to a successful conclusion. By far the wisest course is to combine all these six methods, and that, as I understand it, is and will be the problem of the Weather Bureau. I hope myself to make some conributions to the mechanical problems of the atmosphere. The first work planned for Mount Weather will, I understand, be along the ourth line, or that of exploration, by means of balloons and kites, a work that now excites the liveliest interest because of the surprising evelations that have come to us through the organized international alloon work in Europe. Doubtless similar surprises are in store for us relative to the condition of the atmosphere high above our own continent. But the mechanical laws, or principles, are the bone and sinew of our whole atmospheric structure. We must understand these perfectly; we must follow them out to the minutest details and then look about to see whether nature confirms our conclusions, and if it does not then we must seek for the reason. In such a mathematical or logical study one is greatly aided and guided by observation and experiment. By means of these he tests himself and his logical processes at every step of the way for fear lest the imperfections of his own argumentation may lead him into some serious accumulation of errors. Now, some such experimental work with air and water has already been provided for in the best schools of hydraulic and mechanical engineering, so that at Mount Weather we may begin with such problems as are ordinarily handled in these schools, since they all have a direct bearing upon some portion of our meteorological work.

You will find many references to these problems in my Meteorological Apparatus and Methods, my Preparatory Studies for Deductive Methods in Forecasting, and in my Mechanics of the Earth's Atmosphere, but in order to have the whole course of work brought definitely to your attention I have arranged them in my next chapter as a handbook, or suggestive guide, which will represent, as far as practicable, the best suggestions that I have to offer. This work has been compiled in part by going over the literature of the subject, which contains many published papers giving clear methods and convincing demonstrations of the simpler problems. Some of the papers are by students who were candidates for the degree of master of arts or doctor of philosophy in American or European universities. The whole taken together constitutes an extensive body of knowledge bearing on the atmosphere, while the fundamental principles will be found developed in the best treatises on physics, thermodynamics, and hydrodynamics. When reading these experimental and mathematical writings we are at the very front, in fact we are on the skirmish line, of modern progress in this branch of science. Ordinarily only the keenest mathematicians and experimenters undertake the work in these fields, but the duty is now laid upon us ordinary men and we must brace up to the work.

VIII. RESEARCH WORK FOR MOUNT WEATHER WITH THE PREPARATORY COURSES OF TRAINING.

As this is the first time that I have been asked for any suggestions as to work to be done at Mount Weather, I would speak with much caution. I have been given to understand, in a very general way, that Weather Bureau officials will be assigned to Mount Weather, some of them to study, others to receive courses of instruction by lectures and courses of training in laboratory experimental work, and that those who do well are expected to undertake special work in research. Observations in magnetism and insolation and aerial explorations by means of balloons and kites have been spoken of as fields of work and study already definitely decided upon. It may be taken for granted that even our best men will require a year or more of training before they begin to struggle with the difficulties of original research, and at present I think I need only make a few general suggestions.

A list of the courses of study and the problems that appear to me to be of present importance in meteorology and that are appropriate for research work at such an institution as Mount Weather has been compiled. While it would be foolish to attempt all of these, or to plan for more than a small part of them at first, still we must review he list in order to make a wise selection of the few with which work should begin at an institution built, equipped, and manned especially for meteorological instruction and research. This short list is too ong to be read at this meeting, and the enumeration of other probems already looming up in the distance would fill a volume. It may be most desirable to arrange those that occur to me just now in six ists, classified in accordance with the means and the men at our disposal.

(*a*) Those that can be attacked from a mathematical point of view without elaborate apparatus.

(*b*) Those that must be solved by the use of large collections of meteorological data, but require no new special observations.

(*c*) Those that require special observations with the ordinary meteorological apparatus.

(*d*) Those that require special new apparatus and perhaps the cooperation of several adjacent stations.

(*e*) Studies that require elaborate apparatus such as is only found n a very well equipped physical laboratory.

(*f*) The development of meteorological research along practical ines bearing on agriculture and business.

Some of the latter classes (*e* and *f*) can not profitably be underaken without the employment of expert physicists, and in any case would require several years for preparation, while the previous classes *a*, *b*, *c*, *d*) can soon be entered upon.

* * * * * * *

[It has been decided to publish the rest of Professor Abbe's very uggestive list of research problems for work at Mount Weather in a pecial handbook for the use of all students of meteorology, and the eader is therefore referred to this forthcoming volume for the emaining portion of this present report.]

Upon motion of Professor Moore the Rev. Father Odenbach, St. gnatius College, Cleveland, Ohio, was invited to address the conention.

Father Odenbach said:

I think it will hardly be necessary for me to express my sympathy and good eling toward this convention. They are recorded in the report of the second nvention, and I do not think I can express them in stronger terms than I did ere. If I could I certainly would. It is quite natural that my sympathy ould go out to the members of the Weather Bureau, because we are all rking along the same line and are interested in one and the same pet science; t I can go one step further and say that so far as my knowledge goes my spect, my interest, and my brotherly feeling for every single member of this nvention are such that I can give no better expression to them than I did at the last general convention. I have been quiet in the discussions. They have been asking me why I had nothing to say. I did not like to get up at every question. Every question brought forward here interested me, but there is one that interests me more than anything else, not directly, but because I am interested in the Weather Bureau. Some time ago a circular was sent to me by Mr. Smith from Columbus asking me to consider certain points with regard to the relationship between meteorology and the schools. Two questions especially I was asked to answer; first, with regard to the teaching of meteorology in the schools, and, secondly, whether we could not make meteorology a profession, such as law and medicine. I have been at colleges and universities since 1871, so I think I can say something about it, but I would warn you against trying to introduce meteorology into the schools proper. You may not know it, but we of the colleges do know it, that we are at loggerheads with the universities. We do not know what to teach. The people want us to teach everything, and you know what a catalogue of "ologies" we have. They start in the primary school to teach physiology and botany, and now they want meteorology. I think that is going on the principle of having a little bit of everything and nothing solid in any one branch. This is a fight—it is a real fight—of university against university, and college against college. We have two parties, and we hope the right party will win, and that is the party that is going back to the old style of university and college. Germany also made the experiment, though they have not been at it so long. It was in much quicker time they found out that they had started on the wrong track, and they are going back. The principle to be followed by you is, that the college and university must be the ground on which you *prepare* your talent, not *develop* it. A former president of Princeton University quoted one of our great men in this country, a shipbuilder. He said, "Professor, don't try to teach your young men how to build ships. Make them intelligent, and I will teach them how to build a ship in a very short time." By the present method we are taking children and grown people and instructing them in all kinds of things, and it is half knowledge we impart. I think for the Weather Bureau the most dangerous man is the one who knows just a little bit about meteorology. He is the one who will criticise you and hit you hard every single time. I think the Weather Bureau should be most exclusive. Half-learned men will be your ruin if they should enter the service, a continual annoyance if they remain outside of it.

If we can not take to the colleges nor to the universities, what can we do? There is the polytechnic school! It can branch out into specialties, and it should have a thorough professor of meteorology.

With regard to the new observatory—Chief Moore has coined a word. I don't know whether you noticed it; this convention he called a "clearing house for ideas."—I would like to start another word, and that is that the new station is going to be a kind of incubator or hothouse for our ideas. I think it is a grand idea, and that station put into my head the notion that the Weather Bureau should be exclusive because your own men are under control, with all the possible facilities in the new experiment station, and if they talk too much you know how to shut them up, but you can not shut up the little girl of 12 or the young gentleman at 20 who has heard something roundabout about meteorology and then turns around and criticises you. We have seen too much of that in the papers: you can not keep these people quiet. They think they know something, and they want to get rid of it in the shortest time possible.

Father Odenbach spoke further of the benefits to be derived from a convention of this kind, emphasizing particularly the informal conferences which took place between meetings. Here he thought was where the clearing-house idea came in; here all kinds of questions were being hatched; every man was going home with some new ideas. He hoped the next convention would meet at San Francisco for the reason that it would then last ten or twelve days, because at previous conventions the informal conferences began when the cars started.

At 1 p. m., 21st, the convention adjourned to meet at 9 a. m., 22d.

METEOROLOGY IN UNIVERSITIES AND OTHER INSTITUTIONS.

At the suggestion of the honorable Secretary of Agriculture the convention planned to devote a part of its time to a discussion of the position of meteorology in the higher educational institutions of the country. With this purpose in view the convention committee addressed a circular letter to the officials in charge of Weather Bureau stations, calling for information on the subject, the special desire being to ascertain the opinions of educators as to the advisability of introducing meteorology into the courses of study provided by the universities and higher technical institutions of the country. The views expressed in the collected statements so thoroughly reflect the thought of some of the best educators in the United States regarding this subject that the circular calling for the information and the replies received are given in full herein.

CIRCULAR.

U. S. DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU,
Washington, June 2, 1904.

The Honorable the Secretary of Agriculture is interested in the general introduction of meteorology into the courses of study provided by the universities and the higher technical institutes of the country. At his suggestion it is proposed that a part of the programme of the convention be devoted to a symposium on the teaching and the position of meteorology in these institutions. It occurs to this committee that the points upon which information is wanted are (1) the universities that now provide courses in meteorology; (2) the character of the courses; (3) the demand for such courses; (4) the didactic value of meteorology as a course of mental training; (5) the commercial or pecuniary value of meteorology as a professional career. Taking these points in order, consideration should be given to location of the schools with respect to Weather Bureau stations; the university revenues available for maintaining the courses, their nature, whether from endowment or from tuition fees or both; the personnel of the teachers, whether devoting their entire time to the subject or teaching it as an incident to some other branch or occupation. Under (2), the character of the course, should be considered the degree of thoroughness, the time devoted, the classes—that is, whether freshman, sophomore, etc., to which given, whether taught purely as an elective or as a major or a minor study in connection with any particular degree; whether a knowledge of the subject should not be made a major subject to some degrees, such, for instance, as civil engineer, specializing in irrigation engineering or hydraulic engineering, etc. Also under this heading should come the manner of teaching, whether by lecture, recitation, laboratory work, etc. The text and reference books should be considered; whether these works are adequate for the purpose; whether new books should be provided. Under (3), the existence of any demand on the part of students, should be considered the number of students that make request for instruction or courses in meteorology and the purposes that prompt the students to study the subject; also whether the demand on the part of the students is met, and if not is it due to a minor importance attached to the subject by the school or to the inability to secure teachers that feel interested and at the same time qualified to give instruction on the subject. Under (4), the didactic value of meteorology, is deserving of consideration the fact that many subjects are avowedly taught simply because of the mental discipline acquired in their study. What is the value of meteorology as a disciplinary study? Sometimes a study followed for such a purpose may later become utilitarian. Finally, the fifth and most important consideration is the value of meteorology to the students as a professional career, or in connection with such a career or with business affairs in general. There is no reason to doubt, if meteorology offered to the student the same visible returns that are offered by the study of law, medicine, botany, geology, or a number of other studies, that we should find courses of meteorology in every university in the country.

It seems to this committee that thought should be given to the utility of the trained meteorologist as a valuable employee in many of the extensive business and commercial enterprises—one who would give his special attention to the bearing of meteorological and climatological conditions upon the peculiarities of the particular business in which he is engaged, amplifying for that business the conditions daily placed before the public by the Bureau, following daily its interests as influenced by weather changes in all its ramifications, and studying the climatic control of its extensions into new fields of operation.

As some of the officials of the Bureau have had more or less experience in lecturing in the universities and the high schools, the committee requests that these officials prepare syllabi of any and every course of lectures delivered by them in such institutions and forward these syllabi to the committee on or before July 1, 1904. These syllabi should be accompanied by statements giving the name of the institution, the time, and the classes before whom the lectures were delivered. The committee further requests that the general subject of this letter be communicated to such educators as may be, from their college connections, supposed to be interested in meteorological science and their opinions obtained and communicated to this committee.

Very respectfully, JAMES BERRY, *Secretary of Committee.*

The replies received indicate that the time of year at which the circular was issued was inopportune. The vacation season was in progress, and considerable difficulty was experienced in the efforts to reach some of the leading educators, from whom it was especially desired to obtain full reports, and it is probable that the information obtained is less complete than it would have been had the circular been sent out some months earlier, or had it been possible to postpone its issue until the work of the coming school year had commenced.

The generally accepted fact that meteorology is given some consideration in all of the high schools of the country was amply confirmed in the replies to the circular. The instruction is generally connected with physical geography, where a partial treatment of the subject is essentially unavoidable. Some simple lessons appear also to be given in many of the lower grades. The instances of this class introduced into the following statement are not for the purpose of showing the full scope of such work, but are offered partly to afford fair illustrations of its general character, and partly because it was at times impossible to separate these particulars from related comments that were considered worthy of record.

Responses to the circular also brought to light a vast amount of work done by Weather Bureau men in an educational way. The methods employed were determined by the varied nature of the occasions, and ranged from impromptu talks to elaborately prepared lectures, with suitable illustrations. Their audiences included school classes, teachers' institutes, chautauqua circles, summer outings, farmers' clubs, science associations, and business men's meetings. These occasional lectures, the importance of which is fully recognized, will not be enumerated in this report, as an account of much of the work thus done has in the past been published in the pages of the Monthly Weather Review. Such of the series, however, as form part of regular and systematic courses now being given at educational institutions by Weather Bureau men, or which represent a definite plan of instruction given in other ways as opportunities offer, are incorporated. In a number of instances the Weather Bureau officials are the sole channel of information proper to the main subject, and therefore must be quoted; and they are also, as a class, in such intimate relationship with the commercial world as to make their individual opinions regarding the pecuniary value of meteorology as a professional career of more than ordinary weight, and some of their remarks in that connection are consequently given.

In the presentation of the facts that follow the statements appear with reference to States, in alphabetical arrangement, except that the New England States are comprised in one group and are given first. No reports whatever were received from Arkansas, Idaho, Indiana, Nebraska, New Jersey, North Dakota, Oklahoma, Virginia, and Wyoming, and no information of importance was obtainable from the few replies received from Kansas and Oregon.

ROBERT DEC. WARD, assistant professor, Harvard University, Cambridge, Mass.:

INSTRUCTION IN METEOROLOGY AND CLIMATOLOGY GIVEN IN HARVARD UNIVERSITY DURING THE YEAR 1903-4.

Geology B²*hf*. Meteorology (elementary course).—Lectures, written exercises, observations, and laboratory work.—Half-course (second half year). Monday, Wednesday, Friday, at 11; laboratory work (two hours a week) in the following sections: I, Monday, 1.30-3.30; II, Tuesday, 9-11; III, Tuesday, 11-1; IV, Thursday, 1.30-3.30. Assistant Professor Ward, assisted by Mr. Walter S. Tower.

Course B is required for admission to courses 1, 2, 3, 19, and 26.

The lectures present the subject under the following headings: The earth's atmosphere: Its composition, temperature, pressure, and general circulation; The moisture of the atmosphere: Dew, frost, clouds, rainfall; Storms: Cyclones, thunderstorms, tornadoes; Weather; Climate.

The laboratory work consists chiefly in the construction and study of weather maps, practice in the use of ordinary meteorological instruments, individual record of observations, weather forecasting, etc.

The text-book is Davis' Elementary Meteorology, and the laboratory manual is Ward's Practical Exercises in Elementary Meteorology.

Geology 1 ¹*hf*. Meteorology (second course).—Lectures, observations, and reports. Half-course (first half-year). Monday, Wednesday, Friday, at 11. Assistant Professor Ward.

Course 1 is open to those only who have passed Course B.

This course is intended to enable students to make a more thorough study of various important atmospheric phenomena than is possible in the elementary course in meteorology (Geology B). The subjects discussed are as follows: Dew: Theories, measurements; Frost: Conditions of formation, prediction, protection; Fog: Valley, lowland, and city fogs, relation to health, utilization of fog, ocean fog and its relation to navigation, Haze; Clouds: Methods of formation, classification, methods and results of cloud measurements, photography, clouds as weather prognostics; Tropical cyclones: Development of the law of storms, directions for handling ships in tropical cyclones, cyclones of West Indies, Eastern Seas, Pacific and Indian oceans, theory of tropical cyclones.

The laboratory work consists in the examination of charts, photographs, diagrams, etc., and in the study of text-books, reports, and articles bearing upon these illustrations. Each student will also make a series of observations on dew, frost, and clouds.

No text-book is used in this course.

Geology 2 ^{2}*hf.* Climatology of the United States.—Lectures, library work, and reports. Half-course (second half-year). Monday, Wednesday, Friday, at 2.30. Assistant Professor WARD.

In Course 2 are considered: The controls of the climates of the United States: The annual, seasonal and monthly distribution of temperature, pressure, winds, rainfall, cloudiness, and humidity; The climates of special areas, as, e. g., the Plains, the Pacific Coast, New England, Colorado, etc.; The relations of the climates of the United States to health, habitability, occupations, and soil products; Irrigation: Its present status, possible future, and dependence upon th annual rainfall or snowfall.

As a part of the work in this course, each student constructs a serie of charts of temperature, rainfall, relative humidity, and cloudines for the United States.

No text-book is used in this course, but students are given reference to a large number of books and reports.

[3 ^{2}*hf.* Climatology of the Eastern Hemisphere.—Lectures, library work, an reports. Half-course (second half-year). Monday, Wednesday, Friday, 2.30. Assistant Professor Ward.]

Omitted in 1904–5.

Courses 2 and 3 are open to those only who have passed Course B and to students in the graduate school having equivalent preparation Course 2 or 3 may be taken in the same year with geology 19, o independently of that course. They are recommended to those wh intend to study medicine.

Geology 19 ^{1}*hf.* General climatology.—Lectures, library work, and a thesis. Hal course (first half-year). Monday, Wednesday, Friday, at 10. Assistant Pr fessor Ward.

Course 19 is open to those only who have passed Course B, and t students in the graduate school having equivalent preparation. It i recommended to those who intend to study medicine.

This course is designed to give a general knowledge of climatolog in its broader aspects. The lectures present the subject according t the following heads: Climatology: Its meaning and scope, and its rel tions to meteorology; Use and treatment of meteorological observ tions in climatology; The astronomical relations of earth and sun, th changes of the seasons; Solar climate; Climatic factors; Controls climate; The climatic zones and their subdivisions; Characteristics an hygiene of the zones; Relations of climate and man, including th climatic control of habitability, occupation, migrations, governmen etc.; Physiological effects of different climates; Acclimatization; Ge logical, historical, and periodic changes of climate.

The text-book is the English translation of Volume I of Hann Handbuch der Klimatologie.

The library work involves the special investigation by each stude of some subject in connection with the course, and the preparation a thesis.

Geology 26. Climatology (advanced course).—Conferences, reports, and thes Assistant Professor Ward. Appointments at the convenience of instructor a students.

This course, which may be taken as a whole course or as a ha course, provides more advanced work in the subjects of Courses B, 2, 3, and 19, and is open only to those who have attained a grade of in these courses. It is intended that the work done in geology 26 should lead to results worthy of publication.

In Harvard University there is an assistant professor of climatology, who has charge of all instruction in meteorology and climatology, and who gives his whole time to this work. An assistant in meteorology gives about ten hours a week to supervising the laboratory work and marking the written exercises and laboratory papers in the course in elementary meteorology (geology B). The numbers and classes of students who took the above-named courses in the year 1903–4 were as follows:

Geology B.—One hundred and forty-one students of all classes, but chiefly freshmen and sophomores in Harvard College, and second and third year students in the Lawrence Scientific School. This course is prescribed for Lawrence Scientific School students who have elected the four years' course in forestry, or in anatomy and physiology. Otherwise it is an elective course.

Geology 1.—Sixteen students, chiefly in the Lawrence Scientific School.

Geology 2.—Sixteen students, chiefly juniors and seniors in Harvard College, and third year students in the Lawrence Scientific School. Also one graduate student.

Geology 19.—Twelve students, chiefly seniors in Harvard College, and third and fourth year students in the Lawrence Scientific School. Also one graduate.

Geology 26.—One graduate student (a Ph. D. in meteorology of the University of Prague).

There is, on the whole, a steadily increasing election of all these courses.

Geology B is given also at Radcliffe College, and was taken in 1903–4 by 10 students.

METEOROLOGY AS A SUBJECT FOR ADMISSION TO HARVARD COLLEGE AND THE LAWRENCE SCIENTIFIC SCHOOL.

Meteorology may be taken as an elective advanced subject for admission to Harvard College and the Lawrence Scientific School, counting one point. A student who takes the meteorology admission examination must also take, or have taken, the examination in physics. The university publishes an "Outline of Requirements in Meteorology, intended for Use in Preparing Students for Harvard College and the Lawrence Scientific School" (8vo. Cambridge, 1902, pp. 16), from which the following extracts are taken:

> *Object of the course.*—The scheme of work here proposed corresponds with that of the course in elementary meteorology (Geology *B*) in Harvard College. Careful and systematic work in meteorology, of the character here indicated, will train the student in scientific methods of investigation, and will make him to some extent a thinker and investigator on his own account. It will also furnish a foundation for later studies in advanced meteorology. This course, however, should give so rational and systematic a knowledge of the leading facts concerning the atmosphere, the weather and its changes, and the physical laws underlying these changes, that it will afford to those who do not pursue the subject further a useful part of their education.
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> *Time necessary for the course.*—The course should occupy at least three hours a week, with supplementary hours for study and observation, for half a school year. It is, however, recommended that the course should be extended through a whole year, at the rate of an hour and a half a week (with supplementary hours as above), in order to give opportunity for observation through autumn, winter, and spring. It

may in this form be combined with a course in astronomy, arranged in the sam manner.

The teacher's share in the work.—The work of the teacher may be indicated unde the following headings: Instruction in the use of instruments; selection of subjec for observation; suggestions for keeping notebooks; guidance in the discussion observations; presentation of the larger and more general relations of the vario subjects studied, such as can not be learned without the aid of text-books or lecture The teacher should encourage the students to discover for themselves, as far as pos ble, the facts and generalizations that follow from their observations. Useful practi in English composition may be had by requiring careful formulation of these resul Students may need much assistance from the teacher at times, especially near t beginning of the course, but as the work becomes more familiar they should be l more and more to themselves, and the teacher should confine himself to planning t order of observations, to giving instruction in such subjects as are not illustrated local observations, and to promoting the discussion of the results that have be obtained by the class.

The teachers' preparation for this work should include a careful study of the g eral subject, such as may be based upon the reference book, Davis' Element Meteorology, supplemented by additional reading, and by practice in the use of t ordinary meteorological instruments and in the construction and interpretation daily weather maps.

Previous preparation of the student.—The earlier study of geography should ha familiarized the student with the thermometer, the rain gauge, and the wind va and their use in simple weather records; weather maps and their elementary int pretation; the observational determination of the variation in the sun's noon altitu and in the length of the day and night with the seasons; and the general distributi of heat belts, prevailing winds, and rainy and dry regions over the world. If th subjects have not been previously taught, it will be impossible to present the wo in meteorology as here outlined without a serious addition to the time allotted to

In the high school, or later years of the academy, physics should prec meteorology.

Notebooks.—Each student should keep a notebook in which careful record made of the instruments used, of the conditions of their exposure, and of the obs vations made. Whenever a special problem involves the combination of reco made by different observers, the source of the combined records should be clea indicated. The records should be duly tabulated and discussed. Inferences dra from the observations must be separately entered on pages opposite to those beari the observations. Distinction must be made between the student's own inferen and those that have been suggested by others. Care should be given to the form all verbal statements in which results are embodied.

The notes should not be crowded. Some space should be left between success topics, and each topic should be marked with a prominent heading. A summary the various topics, which will be necessarily encountered in a somewhat unsystema order during the progress of the observational work, should be finally made acco ing to some systematic scheme. An index should be appended.

Examination.—The candidate presenting meteorology as an admission subject w be required to take both a written and a laboratory or practical examination. T written examination may test his understanding of observational methods appropri to the subject, but will call chiefly for a knowledge of facts and principles. T laboratory or practical examination will test his skill in observation as well as grasp of principles. This examination can be taken in Cambridge only; for th who are examined elsewhere in June, it will be postponed to September. It m include the use of instruments, the discussion of observations, and the construct and interpretation of weather maps and climatic charts.

The candidate will be required to present at the time of the laboratory or practi examination the original notebook[a] in which he recorded, with dates, the steps a results of the observations which he made at school. This book must bear indorsement of the teacher, certifying that the notes are a true record of the pup work. The notebook is required as proof that the candidate has formed the habi keeping a full and intelligible record of his work through an extended cours observational study and that his work has been of a satisfactory character; but grea weight will be given to the practical or laboratory examination than to the noteb in determining the candidate's attainment.

The sling psychrometer (which may be used as an ordinary sling thermomet

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[a] This requirement is not intended to prevent the use of a rough memoran book for outdoor work in which the regular notebook might be injured.

he maximum and minimum thermometers, the rain gauge, and some form of ba-
ometer are the most important instruments. A wind vane on a neighboring build-
ng may save the expense of buying such an instrument. The other instruments, as
bove suggested, should be added when possible, but it is hoped that no teacher
vill postpone the establishment of a course in observational meteorology solely
ecause a full set of first-class instruments can not be bought at the outset. Much
an be done with less expensive instruments than those in the above list. The instru-
nent shelter, in which the thermometers and thermograph should be exposed, may
dvisably be built outside of one of the windows of the school building.

Books, etc.—Davis: Elementary Meteorology. Ginn, Boston, 1898.

NOTE.—There is no text-book covering the course as here described, but this will
erve as a reference book in the nonobservational part of the work.

Ward: Practical Exercises in Elementary Meteorology. Ginn, Boston, 1899.

NOTE.—This book is used in the laboratory work of the course in elementary
eteorology in Harvard College (Geology B), to which the meteorology of the
dmission examinations corresponds.

Greely: American Weather. Dodd, Mead & Co., New York, 1888.

Scott: Elementary Meteorology. International Scientific Series, London, 1889.

Abercromby: Weather. International Scientific Series. Appleton, New York,
87.

Waldo: Elementary Meteorology. American Book Company, New York, 1897.

Archibald: The Story of the Earth's Atmosphere. Appleton, New York, 1898.

Smithsonian Meteorological Tables. Smithsonian Institution, Washington, 1893.

Instructions for Voluntary Observers.

Instructions for Use of Maximum and Minimum Thermometers.

Instructions for Use of the Rain Gauge.

Barometers and the Measurement of Atmospheric Pressure.

nstructions for Obtaining and Transcribing Records from Recording Instruments.

nemometry.

OTE.—These pamphlets, all issued by the United States Department of Agricul-
e, Weather Bureau, and obtainable on application to the Chief of the Weather
reau, Washington, D. C., will be found the best guides in making observations,
care of instruments, etc.

aily weather maps, issued from the nearest station of the Weather Bureau, and
t free of charge to schools, are a necessary part of the equipment in this course.
e Monthly Weather Review (costing 20 cents a number), the bulletins, blank
ather maps, and other publications of the Weather Bureau, which may be secured
m the Chief of the Weather Bureau, as above, and the various publications of the
nate and crop services of the different States, will also prove useful.

bservations.—Observational work in meteorology should include a considerable
iety of the subjects given in the list below, but it is not expected that any one
olar can accomplish all that is here outlined. Examples should be selected from
list, as opportunity offers, so that each scholar shall become familiar with at
st fifteen problems, not less than two being taken from each of the seven head-
s given below.

ew of the problems here suggested call for continuous routine observation at fixed
rs; they require, on the other hand, an intelligent examination of ordinary
ather phenomena with special reference to discovering their explanation. In most
the problems, a small number of observations will suffice. Much time may be
ed by cultivating a habit of promptly attacking the work in hand. Under the
ervision of the teacher, different problems may be assigned to the several mem-
s of a class; or several scholars may work on different parts of the same problem,
hanging records in order to save time. It is expected that all the scholars will have
eneral knowledge of the results which have been obtained from the observations
de by the other members of their class. The teacher will use his discretion in arrang-
the order of the problems, and in selecting those that are best suited to the season
which the work is done, to the locality in which the school is situated, and to the
lities and apparatus at command. Although the variety of accessible prob-
s is less in city schools than in country schools, much may be done in the city as
l as in the country.

he essence of the observational work does not lie in the performance of specified
s, rigidly defined and alike for all schools, but rather in the cultivation of a
it of scientific inquiry by the practical study of atmospheric phenomena. The
nature of these phenomena becoming known by actual observation, rapid
ance may be made in knowledge of the distribution of similar phenomena by
ns of the nonobservational, or text-book portion of the course. It is believed
by a judicious combination of these two kinds of study, the advantages of both

may be preserved, while the disadvantages of slow progress through purely inductive work, and unsound progress through purely didactic work, may be avoided.

(Then follows an outline of the problems that may be done by means of the observational work, under the headings, Temperature; Winds; Humidity; Dew and frost; Clouds and upper air currents; Precipitation; Pressure, and Weather maps.)

General remarks.—A review of the seven preceding headings will show that a very general correlation exists among them, whereby the subjects of every heading are associated with those of nearly every other. In other words, every weather element is treated as a function of several other elements. It follows from this that the variety of work here outlined is more apparent than real, and that many problems which appear from their wording to be entirely new are in large part rearrangements of problems previously encountered. A review is therefore less necessary at the end of such a course as this than it might be in a course where the last heading was entirely unconnected with the first.

Nonobservational work.—The nonobservational or text-book portion of the course should supplement the observational work. It is intended to present the larger and more general principles of meteorology, which can not be gained through local observation, but which serve to show the correlation of the various local phenomena with their fellows elsewhere over the world. As in the previous division of the course, much must necessarily be left to the teacher, both as regards the selection and order of additional subjects presented, and as regards the illustration of these subjects; but an essential for the satisfactory extension of the course under the present heading is that the topics here introduced should have been first encountered more or less directly in the problems of local observation.

In the following pages reference is made to appropriate chapters of the text-book.

The number of students who take the admission examination i meteorology is still small, averaging thus far less than ten or twelve a year, but it is growing. These examinations have been given since June, 1900. They have therefore been in operation only four years. Obviously, the chief reason for these small numbers is that the schools do not offer the necessary instruction in meteorology which would put their pupils in a position to take the examination. Among the schools which at present offer adequate and systematic instruction in mete- orology, and which have sent candidates in meteorology to Harvard, may be named the Brookline, Mass., High School; the Middlese School, Concord, Mass.; St. George's School, Newport, R. I., and the Worcester Academy. At Milton Academy, Milton, Mass., althoug no candidates have thus far come from there, Mr. W. L. W. Field give instruction in the taking of simple meteorological observations in con nection with geography teaching in the lower classes. The academ has some good instruments, including Richard barograph and thermo graph. Mr. Field encourages "all the boys to take an interest in th records and study the progress of storms, etc." At the Middlese School in Concord Mr. R. H. Howe says:

> We are giving two thirty-five minute periods a week to meteorology, both of then laboratory work, the preparation outside taking two hours a week. Last year th class included 4 boys, and this year the class consists of 16. The subject was taugh last year in the third class, and I am sending up this year 1 boy for preliminar examinations. This year it was taught in the fifth class, and was given only as half-year course. * * * Besides their class-room work, the boys have had con tinuous practice throughout the course in reading instruments and taking ordinar weather observations, recording these in their notebooks. During the course the have also had to write five theses of not less than eight pages on the various weathe instruments and their history.

The fact that Harvard sets admission papers in meteorology ha certainly had a very stimulating effect upon the teaching of the sub ject in many of the schools which prepare boys for this university.

INSTRUCTION IN METEOROLOGY AND CLIMATOLOGY AT OTHER COLLEGES AND INSTITUTIONS OF SIMILAR RANK IN MASSACHUSETTS.

Although several letters of inquiry have been sent to the colleges in Massachusetts outside of Harvard, replies have been received from he Massachusetts Institute of Technology and from Williams College nly. At the Massachusetts Institute of Technology during the past winter, Mr. H. W. Shimer gave a course of 30 lectures in general limatology, including also the elements of meteorology, the outline f the course, as given in the catalogue of the institute, being very much like that of geology 19 in Harvard University. Six students were registered in this course.

At Williams College, Professor Wilham has, during the past college ear, given a half course (elective) in meteorology, which was open o juniors and seniors, and was taken by 19 students. Davis' Elementary Meteorology was used as the basis of the instruction, and umerous lectures were given. A syllabus covering both text-book nd lectures was closely followed. "Practical work was done in making some meteorological observations, in deriving laws from meteorological statistics, and in making weather forecasts." This was a hree-hour course, with the practical work in addition.

GENERAL REMARKS.

I am of the opinion that some study of meteorology should be equired of all persons who are fitting themselves to serve as physicians, irrigation engineers, geologists, etc. The chief difficulty with he present unsatisfactory status of meteorology as a school study in his vicinity is that the subject has no recognized standing, and must herefore usually be wedged in where there happens to be an opening nd when the teacher happens to be an enthusiast. A marked increase n the interest in meteorology, and in a more general and more systematic teaching of the subject was observed to follow several courses f lectures, accompanied by practical work on the weather maps, given y myself to classes of teachers within 20 miles or so of Boston during he past ten years. These courses of practical lessons consisted of five r ten meetings, of an hour each, usually held in a school building at p. m. The charge for the lessons was a nominal one, and payment was asked, not because the instructor wished to secure some financial return for his time, but because it was felt to be better that the teachers should themselves pay something for the instruction received. These courses were inaugurated under the auspices of the New England Meteorological Society, and were continued by me until my regular work at Harvard became so extended that outside lectures had to be given up. The adoption of meteorology as an admission subject to Harvard College and the Lawrence Scientific School has, as previously tated, helped greatly to stimulate the study of meteorology in the chools which prepare for Harvard, but chiefly in those schools where he instruction is given by recent graduates of Harvard or Radcliffe.

As to the value of meteorology as a professional career, there is no oubt that were students of geology, botany, zoology, medicine, engineering, etc., all required to take courses in meteorology, the teaching f the subject would at once be extended and improved throughout the ountry, both in schools and colleges. This would mean a greater demand for teachers of meteorology. That there is opportunity for persons skilled in meteorology and climatology to make themselves useful and valuable in many different lines of business activity there is no question. In my own teaching I lay more and more emphasis on the practical application of the facts which my students acquire, and, in climatology especially, I show the importance of climatic control over the occupations and activities as well as the health of man. But there certainly is no career open to any considerable number of trained meteorologists.

J. Warren Smith (United States Weather Bureau, Columbus, Ohio), New Hamshire College, Durham, N. H.:

In reply to a letter to Prof. C. H. Pettee, of the department of mathematics, he states that the college has given a course in meteorology since the opening of its doors to students in 1869. Since 1876 it has been taught by Professor Pettee as an incident, his main work being the teaching in mathematics. The course has always been open to juniors and seniors, and thirty exercises are allowed. Usually it has been taught purely as an elective, although sometimes it has been required in the regular agricultural course. It has been taught by text-book, supplemented by short talks, and by reference to the works of Redfield, Espy, etc., for the earlier history of the subject, and to those of Ferrell for the mathematical elaboration of the theory. Davis' text-book has been used since issued and has proven very satisfactory. The daily weather maps are found of value.

There have been few years since 1869 that meterology has not been elected by the number required to secure the course.

Willis I. S. Wilham, Field Memorial Observatory, Williams College, Williamstown, Mass.:

I have a junior and senior elective course which comes three times a week. I use a text-book, Davis' Elementary Meteorology, as the basis of the instruction, but numerous lectures are given and the work is systematized by a syllabus which covers both text-book and lectures. Quite a little practical work is done in making meteorological observations, in deriving general laws from meteorological statistics, and in making weather forecasts.

There were nineteen men who took the course this present college year, and I think that I will have about twelve men next year. It would seem that there are always a few men who would take such a course even if it were a hard one.

I should consider its didactic value almost the same as that of any other natural science. Physics, chemistry, and biology are of course more fundamental sciences, and meteorology should not be studied if any of these three must thereby be omitted. I know nothing about the commercial and pecuniary value of meteorology.

Robert Marshall Brown, instructor in geography, State Normal School, Worcester, Mass.:

The State Normal School is maintained altogether by the State.

The subject of meteorology is in the hands of the teacher of geography. It is taught as a portion of geography.

Not a great deal of time is spent on the subject. The idea is to furnish the students with some of the broader considerations and their plications. More time is spent on the phenomena as observed from y to day. Some laboratory work is done, as well as what might be med fieldwork.

The demand for the subject is, of course, conditioned by other things. our normal school the distribution of time and subjects is so arranged t not a large share falls to any one teacher, but the student as a re teacher is always our objective.

eteorology has a large place as a disciplinary subject. This is, ever, not realized because of a superficial grasp of the subject. I speaking now from the standpoint of the secondary and grade ols.

ur consideration of the subject is from the teacher's standpoint. hope to give our students a sane and safe view. While we can over a great deal of ground, we can set them in the proper atti- and direct them along a way which they must afterwards travel or less alone.

M. **Greenlaw**, in charge of Science Department, Rogers (Public) School, Newport, R. I.:

ch member of the senior class in physical geography is instructed ading the standard barometer with vernier and is made responsi- or daily observations for a stated time, and is also instructed in ng the wet and dry bulb thermometers, and determining the rela- humidity. The results are recorded by the class and plotted. tice is given in interpretation of weather maps—the paths of n centers across the country are plotted on blank maps, and prac- is given in reproducing weather maps by platting the data of sure, temperature, wind, and precipitation, and drawing isobars isotherms. The changes in weather during the passage of a ne-anticyclone are considered, and the importance of the weather ictions and of the work of the United States Weather Bureau is t upon. It is proposed to inaugurate a private station at the ol.

illiam P. Bartlett, A. B., Tyringham, Mass.:

own University is my alma mater (A. B., 1878). The telephone being brought to a working degree of perfectness during my se there, and Professor Blake was perfecting the transmitter. ibly in the scientific course at that time meteorology was studied. d by the catalogue 1903–4 that the subject is now given some inence as an elective. On page 33, under "Physiography," it is ed in an elementary way. Again, on page 60, it appears under ysical geography:" "Three hours. First term. Elective for omores, juniors, and seniors," and is assigned to a full professor. udge that meteorology as a course of mental training should have h didactic value. For careful and delicate induction it must have t value. For nice discriminating deduction it introduces a class cts that change the definition of "exact science" that has crippled se of the syllogism.

seems to me that the commercial and pecuniary value of meteor- must be more and more recognized, and that the value of the ce as a professional career will increase proportionally. Aptitude s successful pursuit should be revealed in the academies and secondary schools.

E. F. **Cauthen**, principal Northwest-Alabama Agricultural College, Hamilton, Ala.:

It seems to me that the pecuniary value of the study would be greatest to that class of men who are making farming a special study, those who are going into truck growing, fruit growing, and floriculture on a large scale. A better knowledge of the laws of nature will aid these in arranging crops, time of planting, harvesting, etc.

George W. **Carver**, director department of agriculture and experiment station, Tuskegee Normal and Industrial Institute, Tuskegee, Ala.:

I am in favor of everyone knowing at least the rudiments of meteorology. I feel that it is just as important as the rudimentary knowledge of agriculture, and, in fact, that it is a part of agriculture, and I am sure that its importance will become more and more clear as it is methodically and scientifically studied. It will show the relations existing between crops and the relation of the farm to other commercial enterprises. As discipline for the mind I am sure that nothing could be better, as the keeping of such a record makes one methodical, thoughtful, accurate, and a close observer. These I consider the four fundamental adjuncts to a well-rounded education.

W. H. **Bowen**, superintendent public schools, Ensley, Ala.:

We have no such course, as a course, but it has close attention in physical geography. We find the use of the daily weather maps quite helpful. We use one in each room above the fourth grade, and find that pupils and teachers become interested in it.

F. P. **Chaffee**, United States Weather Bureau official at Montgomery, Ala., forwards outlines of eight lectures that he has delivered at various points in the State during the past four years. While not forming a consecutive course, these lectures are closely related, and deal in the main with the work of the Weather Bureau in its bearing on agricultural pursuits.

M. E. **Blystone**, United States Weather Bureau, Phoenix, Ariz.:

Meteorology forms no part of any of the courses of the University of Arizona, except in so far as it is connected with physical geography, which is taught in the subcollegiate department. This is the only institution of learning in Arizona of the class mentioned in the circular.

A. G. **McAdie**, United States Weather Bureau, San Francisco, Cal.:

A series of lectures was delivered by the writer at University of California, Berkeley, in 1900. These lectures formed part of Course I, Astronomy, and were given in the students' observatory. The average attendance was about 150. The lectures were all illustrated. Students took notes and were required to pass examination at the close of the term, the examination papers being marked by Professor Leuschner.

Owing to press of official business the writer has been unable to give further courses. The presidents of both universities (Leland Stanford and University of California) have been urged to select suitable instructors in meteorology, but this they have not done as yet.

Leroy Anderson, director, California Polytechnic School, San Luis Obispo, Cal.:

We are giving some instruction in meteorology as a part of the course in physical geography. The work is given in three ways—recitation, lectures, and laboratory work. Our instructor, Mr. Twombly, is very much interested in the matter. We have on hand a maximum thermometer, minimum thermometer, and rain gauge, these comprising our meteorological instruments at present.

William F. Slocum, president Colorado College, Colorado Springs, Colo.:

One course has thus far been given in meteorology at Colorado College. It is known in our catalogue as "Astronomy D." The text book is Davis' Elementary Meteorology. Three exercises a week are given to the class. There are recitations with informal lectures, and suggestions are given from time to time to the various students of the principles involved in the study of conditions affecting the weather. It has been the habit in most years to require, besides the acquaintance with the text-book, that an essay should be written from material found in the library on some assigned topic bearing upon the use of weather maps and such drawings as can be secured. This course is elective, but it counts in the work which is being done at Colorado College for the degree of bachelor of arts, and it is elected by students from all classes. A fuller course in meteorology is to be given in the future as a part of our engineering course.

The class in meteorology usually numbers from 15 to 25. As a rule these students have not any professional interest in the subject—that is, they are not looking forward to an application of meteorology, either in a college or in business—but they appear to be attracted by a special interest which they have in the subject. It seems to our instructor in meteorology, Dr. Frank H. Loud, that this study is of value for training in habits of observation, as well as for the information it gives in regard to the subject which it treats.

L. G. Carpenter, director Agricultural Experiment Station, State Agricultural College, Fort Collins, Colo.:

The agricultural college has always shown an active interest in meteorology, from its very inception, and has maintained records since the opening of the institution. In the organization of the experiment station, this was transferred to the experiment station, and a meteorologist was elected in connection with the work of the section and irrigation division engineer. It may be well to say that such work has not had entirely the same purpose as the Weather Bureau. We have developed a large equipment and maintained a large series of records. This gives a laboratory means for study, and some students are given work in this connection.

A course in meteorology is given and has been given since 1889 or 1892. It has been a descriptive course for several years, given by means of lectures, but more recently from text-books. As the time has been too short to make a connected study of the subject, more especial attention has been given to the understanding of the movements of the atmosphere, of the laws of storms, and of the features of climate. These courses have been given to certain sections of the classes in agriculture, domestic science courses, and engineering.

The didactic value of meteorology in mental training I would put on about the same plane as most other sciences. As a matter of information, certain general principles are needed by every well-informed person. To study the laws of storms by charts may be of high interest and high educational value. In that respect it is perhaps better adapted for the development of an average student than many of the other sciences.

I have not seen any great opening for young men in meteorology, and consequently would not feel like recommending any person to take up the work with that end in view.

In the case of the State Agricultural College the whole institution is maintained by the funds of the college. The equipment of instruments includes barometers, thermometers, rain gauges, barographs, thermographs, wet and dry bulb thermometers, anemometers, etc., an outfit which amounts to several thousand dollars. Of course, this equipment is used for constant practical work, and teaching is subsidiary, but in that very fact it sometimes produces the best effect. The teachers give only a portion of their time to this subject—in fact, it may be said to be an extension of their other work. The time devoted is about six weeks. The course is given to a mixed class of seniors and juniors, and has been required of students in civil engineering, students in agriculture, and the lady students.

There is no particular demand by the students for instruction in this study. The pressure on the part of the students more directly connected with special lines has been so great, and always has, for that matter, that the object at present is to give as good a general view of the subject as possible.

The Experiment Station has issued some other reports in connection with the weather, but a greater part of the work has been unpublished.

RICHARD H. SULLIVAN, United States Weather Bureau, Grand Junction, Colo.:

There are no universities, colleges, or academies in this locality. Our high school course prepares a student for entry into the college freshman class.

Meteorology is taught incidentally as the study of physics and other sciences bear upon it, and also to the extent usually covered by the physical geography. The subject has no weight whatever in the test examinations, except in so far as it shows familiarity with the other subjects.

Physics is taught in the junior year; physical geography in the sophomore year; biology, including zoology and botany during a portion of the term, in the freshman year, and geology in the senior year.

The courses in science are covered by lecture, recitation, and laboratory work. The practical demonstrations in the meteorological bearing have been made when the classes visited the local office. It is believed that the simplest form of elementary meteorology should be used, and Waldo's work has been recommended, although the present principal of the high school has been advised to obtain a copy of Davis.

The demand is not upon the part of the students. There is a feeling here on the part of a large number of patrons of the schools, including the members of the school board, that the course is sufficiently wide in its scope. We have recently passed through a canvass for the election of a new member of the school board, and much was said about faddism and the introduction of extraneous subjects in the school course. The election resulted adversely to the methods heretofore pursued, and the newly organized board selected a new superintendent. The introduction of a new subject must have the indorsement of this board. As the new superintendent is not conversant with existng conditions, I have obtained expressions of opinion from Mr. E. E. Cole, principal of the high school, who is not only a fine teacher but a progressive student, and more than favorable to the introduction of meteorology as a separate study, believing it necessary to enlargement of the knowledge of one of the main departments of physical geography. However, under existing conditions, Professor Cole is willing o incorporate meteorology as a side or minor study on his own preogative in connection with the other sciences and in a much larger egree than formerly.

It has not been lack of ability or willingness on the part of the eacher to become more familiar with and teach the subject, but the ime has been fully occupied in making effective the methods of the ormer superintendent. Whenever opportunity offered, the official n charge has tendered the good offices of the service toward enlarging pon the knowledge of meteorology, as shown by a demonstration of he practical methods of the Weather Bureau. Professor Cole has onored the observer with an invitation to deliver a series of three ectures to the students of the high school during the coming winter, ame to be given during stated evenings and illustrated, as far as racticable, by lantern slides, a series of which is now being preared by me for a lecture before the Western Colorado Academy of ciences, on August 5.

Professor Cole says that meteorology should be, and is, classed as a isciplinary study, just as physics, astronomy, botany, and other ciences are. The net result would be that, now and then, a student would elect to pursue the study of meteorology more deeply, and thus make material for the Weather Bureau or other meteorological demands of the country.

The commercial or pecuniary value of meteorology as a professional career is problematical. It is thought the study will never offer the pecuniary returns obtained in law or medicine or in astronomy, botany, or geology, whose fields for experts are necessarily limited to professorships in schools and colleges and to the demands of the Government for the increase of general knowledge. By far the larger percentage of students electing to take up the study would do so with a view to reaping visible benefits by service in the Weather Bureau. The demand for such material is always, at all times, of such a limited character that the Bureau offers practically the only field to the trained meteorologist. No extensive commercial enterprise will incur the expense of an expert when the whole field is covered by the Weather Bureau and the desired information can be obtained for the asking. Any student electing to take up the subject with a view to making meteorology a profession would naturally desire practical instruction in the Weather Bureau. In such a case, and in the event a trained meteorologist was needed in connection with a private business enterprise, the Bureau, by directing the study of the science, would be serving public interests just to that extent. However, should the lemand for such services increase more rapidly than at present anticipated while this public service is being performed, the usefulness o the Government service would be very largely supplanted by that o individuals uncontrolled by conservative methods, thus laying th foundation for an increase in the crop of long-range forecasters, an the prestige of practical meteorology, built up at the expense of lon years of diligent work against prejudice, direct opposition and nonc operation, might possibly suffer thereby. The value of such inde pendent services can only be enhanced by pulling to pieces the fabri of the Weather Bureau in efforts to attract attention to the individ uals themselves as against the great work done by the Governmen This is another, and possibly the narrow, way of viewing the matte and the condition may never come to pass; but human nature is th same the world over, and it is only human to look in the directio from which come the greatest returns.

Herbert A. Howe, director, Chamberlin Observatory of the Un versity of Denver, University Park, Colo.:

A few years ago a term's work in meteorology was offered in ou institution, the intention being to use some text-book like Davis. A there was no demand for the course, it was dropped after a while. I we had a regular meteorological station at University Park and som one could give his time to it, it would doubtless be possible to arous the interest of the students. Meteorology could be made an interest ing and valuable study.

W. L. Floyd, professor of natural science, East Florida Seminary Gainesville, Fla.:

We have no course in meteorology, but pay attention to the subjec in connection with the study of physical geography and geology.

I consider the subject of meteorology of great importance to Florid students, where so much depends on the successful growing of fruit and vegetables, so greatly influenced by climatic conditions.

Andrew Sledd, president University of Florida, Lake City, Fla.

We have not hitherto offered any courses in meteorology. Th demand for such courses is, so far as I am aware, practically nil. Th constituency of an institution must have a good deal of preliminar instruction before any strong demand for such work can arise.

I should suppose that the didactic value of meteorology would b considerable, but not in itself sufficient to originate or maintai departments for instruction in that science, because other sciences o immediate and self-evident utility and value offer equally good menta discipline and reenforce it with practical financial claims. It wil devolve upon meteorology, therefore, to establish itself in our college and as a professional career, not on the basis of any superior didacti value, but on the basis of a didactic value equal to that of the othe sciences and enforced by a practical utility and pecuniary rewar equal, and, if possible, superior, to that which attaches to the study o other sciences.

In other words, meteorology and chemistry, for instance, posses equal value as mere implements of instruction. But chemistry po sesses, besides this, a very distinct practical utility, and holds out t its students a strong promise of pecuniary reward. Does meteorolog possess this practical and immediate utility? There may be differenc of opinion, but I should suppose that it does. But what of the promi of pecuniary reward? Can meteorology make any, and if it promised, could it make its promise good? In the present situation of affairs I believe that a negative answer must be given to this question, and just here lies the essential defect in meteorology's claim for consideration. Whether rightly or wrongly, our people are in the habit of asking of every plan or policy, "Will it pay?" and if that question is not answered satisfactorily the proposed plan or policy has an initial load to bear, an initial difficulty to overcome, that will be too great, in my judgment, to be counterbalanced by any other claims that meteorology, as a professional career, can establish.

I say "as a professional career;" but I do believe that meteorology has, and can easily establish, a strong claim upon the consideration of the scientific farmer, and here, if I were making a formal argument for meteorology, I would make my plea against the allegation—valid, I believe, at present, from the professional standpoint—that meteorology does not pay. Meteorology would not now pay as a professional career because there is too little demand. But it would pay as a valuable adjunct in the training of the scientific farmer.

I believe that proposition to be incontrovertible. If the people become convinced that it is so the whole agricultural population will come sooner or later to demand meteorological information and instruction. What will be the result? This popular demand must be met by men competent to give the required instruction, and thus a class of professional meteorologists will be created, and meteorology will offer adequate financial promise as a professional career.

But it seems to me that it is only in this indirect way—through its relation to the farmer—that this science can make its place. Let me outline: If meteorology be helpful to the scientific farmer, then all agricultural colleges should offer instruction in that science. This opens a few doors for "professors." With the diffusion of meteorological information and the conviction of its practical utility and financial value, the demand for instruction increases. More "professors" are needed. The science becomes more elaborate and differentiated into diverse subdivisions. More and more "professors," "consulting meteorologists," etc.—and thus, from the interests of the farmer comes a great and highly elaborated profession, which continually elevates and widens the science with which it deals.

B. BUNNEMEYER, United States Weather Bureau, Pensacola, Fla.:

The writer gave a series of lectures, systematic in plan, to the high school classes of Pensacola in the spring of 1904. The time of instruction was from 2 p. m. to 3 p. m.; eight lectures were given at regular intervals from March 8 to 28, and in the latter part of April were followed by visits of the classes to the Weather Bureau Office, where they were made acquainted with the various instruments in use and with the practical work of the service.

The various subjects discussed followed very closely the order adopted in Waldo's Elementary Meteorology, and were illustrated by frequent blackboard drawings. The pupils in attendance numbered 50, of both sexes. No regular course in meteorology is provided by this school (Public School No. 1), nor is any special time devoted to this instruction, except as an incident to physical geography, but both pupils and teachers were much interested in the lectures.

W. N. **Sheats**, superintendent State educational department, Tallahassee, Fla.:

It is my impression that practically no attention is given to meteorology in the colleges and universities of the State. Of course, if not given, there is no course provided and no demand for such courses. I think there is great didactic value in such a course if our young men could be educated far enough to appreciate it. I think the pecuniary value of meteorology as a preparation for a professional career is inviting. I do not think that there are a dozen teachers in the public schools of the State that give the subject any consideration at all.

N. R. **Taylor**, United States Weather Bureau, Tampa, Fla.:

There are no schools in this city that teach meteorology, but Professor Mallicoat, who is at the head of the Tampa Preparatory School, has requested that, beginning with September next, when his school reopens, the writer devote an hour each week to the instruction in meteorology of a class of his advanced students. The superintendent of public instruction has also requested that an occasional lecture be given to the students of the Tampa High School.

Thomas R. **Baker**, professor of natural science, Rollins College, Winterpark, Fla.:

We established a course in this branch about seven years ago and continued it for several years, but it became necessary to discontinue it on account of lack of time on the part of the science instructors to give the subject the time and attention that its importance demanded.

Our classes in meteorology were generally filled by students requesting to study the subject.

The demands of the course were not fully met, largely on account of our not having the necessary apparatus to enable us to do accurate work. If institutions like ours were provided by the Government with suitable apparatus for meteorological work, there would be a great incentive created for pursuing this study.

Teachers who are interested in the subject and who are qualified to give instruction in it can be secured without difficulty.

My opinion is that the study of meteorology has considerable didactic value; as a disciplinary study especially it is very valuable, if it is taught properly, with the use of accurate apparatus.

It seems to me that the study of meteorology as a professional career offers exceptional opportunities for usefulness, and that its study as such a career should be encouraged; and it also seems to me that it can be pursued with great profit, both to the student and to those whose interests might be affected by his work, in connection with business affairs.

J. R. **Weeks**, United States Weather Bureau, Macon, Ga., reports the giving of eight lectures within the past year to schools and educational societies in and near Macon, Ga. The audiences numbered in most cases about 200. The lectures were simple in scope and were illustrated with stereopticon views. A list of more than 150 views, comprising well-selected meteorological features, was forwarded by Mr. Weeks with his report.

OTIS ASHMORE, superintendent public schools, Savannah, Ga.:

I believe that the science of meteorology will demand more and more attention in the courses of study in our higher institutions of learning as meteorological causes and effects are better understood.

That the subject is of immense practical value there can be no doubt. An intelligent understanding of its leading facts and principles should be a part of the educational equipment of every college man, and for this reason liberal provision should be made for this subject in the curriculum of every college and university.

When we consider the pecuniary value of meteorology in a professional career, we at once are confronted with the necessarily limited demand for experts in this field. This consideration, together with the ever increasing demands made upon the time of the student by the wonderful practical development of all the sciences, must tend to limit the scope of meteorological teaching in a large number of even our best colleges and universities.

The science of meteorology, however, is yet in its infancy. It needs still a greater development, which it will doubtless receive, and a limited number of experts in this science will always be in demand. Moreover, the applications of the science are national in scope and character. Hence, one or more special schools for teaching all that is known of the subject, for training experts in this science for practical work, and for investigating more fully the laws and phenomena pertaining to the subject should be established, equipped, and maintained in the most efficient manner by the General Government.

W. B. DAVIS, professor of physics, Southern Illinois State Normal University, Carbondale, Ill:

The Southern Illinois State Normal University is the only educational institution that I know of in this section where a course in meteorology is provided. The course will be connected with my work in physics, and will be taught by lecture and laboratory work.

Our new library has just been occupied, and we now have room for the installation of our weather outfit. One of the items in the budget for the meeting of the next general assembly will be regarding this.

We wish to become a substation with complete equipment, and to distribute forecasts, especially to public schools in our territory. Students have taken much interest in what we have been doing, and many are now using your forecasts in their schools.

L. C. MONIN, dean, Armour Institute of Technology, Chicago, Ill.:

The authorities of Armour Institute of Technology are very much in favor that courses in meteorology should be established in the leading colleges of the country. The best place, however, for such courses would seem to be in the agricultural colleges, the normal schools, colleges of naval architecture, and military schools.

With regard to colleges of engineering, such as Armour Institute of Technology, it would seem that the courses at present are too crowded with subjects, so that any addition which has no direct bearing upon the problem of engineering would seem superfluous. There is no doubt but that the study of meteorology is valuable, not merely from the utilitarian point of view, but also as a disciplinary study.

R. D. Salisbury, professor of geographic geology, department of geology, University of Chicago, Chicago, Ill.:

The University of Chicago gives several courses in meteorology during the year. There are two twelve weeks' courses, the one being the duplicate of the other, and two six weeks' courses, the one being the duplicate of the other. The courses in meteorology are given in connection with the departments of geology and geography. There is no separate appropriation for these courses, but the necessary money is appropriated from those departments. The instructors do not give their entire time to this subject; indeed, the instructors are not themselves professional meteorologists.

These courses deal primarily with the principles of meteorology and not with observational work, although the latter is not altogether neglected. The longer courses are based on such books as Davis Meteorology, Waldo's Meteorology, etc. The longer courses are elective and the classes are made up of students of different stages of advancement. They are rarely freshmen, and may be from almost any other year of the college course. There are more juniors, seniors, and graduate students than students of less advancement.

A considerable number of students take these courses regularly. Without looking up statistics in detail, I should say that the number taking the twelve weeks' course may be from thirty to forty each year, while the number taking the shorter courses is probably twice as great. The instruction given meets the demand for the most part, as the students taking it are generally intending teachers of geography, physiography, etc. There is occasionally a student who wants a professional course in meteorology. This we are unable to give him at present.

It seems to the instructors giving these courses that the educational value of meteorology is as great as the educational value of other sciences. From some experience in this work, I should not put it behind any other subject I know in its adaptability to develop the student.

As to the commercial or pecuniary value of meteorology, I can say little. Our courses are not intended to develop professional meteorologists, but they are intended to fit teachers for handling this subject in connection with public school work.

It is the hope of the university that we may some time have a full equipment for meteorological work. I hope it may be possible to make some arrangement with the United States Weather Bureau here in Chicago. The officers of this station have always been very kind in admitting our students and illustrating their methods of work.

S. W. Beyer, department of geology and mining engineering, Iowa State College, Ames, Iowa:

At the present time we give no course in meteorology alone, but include several weeks' work on the principles of meteorology in our course in physiography.

The work is conducted by lectures, supplemented by a study of the instruments used in the weather service and by the construction of maps and charts and their interpretation. About eight weeks are devoted to the subject.

The work is required by students in the horticultural and agronomy courses in the division of agriculture and in the science course.

I believe that the didactic value of the work in meteorology is just as deserving of consideration as that of any other of the sciences.

H. H. **Seerley**, president Iowa State Normal School, Cedarfalls, Iowa:

We give instruction in our school in many matters concerning meteorology in connection with our work in physiography, and make daily use of the maps, keeping them posted in the library and having them used in the class rooms by our teachers, and consider the subject as very important and necessary in the understanding of much of the work in physiography. I am very sorry that Miss Grace W. Knudsen, who has charge of this work, is unable to answer the full inquiry, but she has left for Europe and will be gone until April. You may be assured, however, that we very much value the work of the Bureau, and are doing the best we can to teach the same so that the teachers of Iowa may be able to complete the work of the Department.

John L. Tilton, department of natural sciences, Simpson College, Indianola, Iowa:

A course in meteorology has been given at Simpson College for the past ten or twelve years as a part of the course in physical geography. Beginning this last year it is given as a separate course.

[The following is an extract from page 54 of catalogue furnished:

Physical geography—(*A*) *Meteorology.*—This course is given in the spring term. Grades in elementary physics are necessary to registration. The various observations on temperature, relative humidity, the dew point, barometric pressure, direction of wind, and cloudiness are taken independently by the different members of the class and the data thus obtained expressed in diagrams or in tables. Following this, the records for several days, taken simultaneously over the entire country, are consulted, and the isotherms, isobars, wind records, and weather conditions drawn on separate outline maps. From data thus considered the class is led to the study and prediction of storms, to the general laws of the circulation of the atmosphere, to the study of climate, and to the relation of climate to human habitation.]

We have a volunteer weather bureau station at the college; we are 18 miles south of the Government station at Des Moines, from which we receive weather maps daily, and many personal favors. We have the use of the scientific apparatus of the department of physics, and, to a limited extent, draw on the funds for scientific work for incidental expenses. These funds are largely from laboratory fees which in their expenditure are combined to defray the expenses on all laboratory work. We also have an endowment of $5,300, the income of which is available for apparatus, though none of it has as yet been used for meteorology.

The instructor in meteorology, John L. Tilton, has general supervision of all the work in science, and is obliged to teach several other classes. His special line of work is in geology and physiography.

While the work in meteorology is here planned for students of the freshman year, it has been elected to a considerable extent by students in all the college classes. They also find sufficient to occupy their attention, and I have seen no evidence that any of them elected it as a "snap." It is required only of scientific students in the senior academy grade and of normal students in their senior year, which is about equivalent to the sophomore year.

The teaching is on the laboratory plan, for which I have developed an outline.

For reference we have the Monthly Weather Review, the books by Ferrel, Davis, Ward, Waldo, Tarr, Dryer, and several other texts which, like the latter, include chapters on meteorology.

As my own outline is essentially a laboratory text, I do not care especially about a new text, though if one that suited me were published I should probably adopt it.

There seems to be quite a demand for such a course. During the past term I had a class of 50, including not only the dozen or so who took it because it was required, but elective students from all the college classes. I do not know why they elect it. Possibly it is because they wish to study the subject, possibly it is because they expect to teach, possibly it is because the subject counts on the hours in science required of them, possibly the fact that no laboratory fee is required of the members of the class has something to do with it, possibly the absence of the president during much of the term caused some to enter the class, possibly my own leave of absence last year caused a few to wait for the return of the regular teacher—for the class was small last year. Probably all of these possibilities had something to do with the size of the class.

The subject gives an excellent chance to correlate information, to apply a student's knowledge of science, to extend his knowledge of phenomena commonly carelessly observed, and to break down errors by cross-questioning, thus leading to carefulness and greater accuracy

A. A. Veblen, department of physics, State University of Iowa Iowa City, Iowa:

[Announcement for the coming year contains the following:

19. *Meteorology.*—Lectures; twice a week. Professor Veblen.
20. *Meteorology and climatology.*—Lectures; twice a week. Professor Veblen.]

Course 19 was given last year, and formed the subject of some correspondence between the Chief of the Weather Bureau and myself The work of this half-year course is to be continued in the second half year, or semester, as course 20, page 158. The lectures are founded on the manuals of Waldo, Davis, Russell, and Hann, for the most part It is the plan to give the students practical work to accompany the lectures.

R. H. Dean, United States Weather Bureau, State College of Kentucky, Lexington, Ky.:

Meteorology is taught in the preparatory department of State College in connection with physical geography, and the class under the direction of Prof. V. E. Muncy is drilled in the use of the daily weather maps in making forecasts. This class obtains a fair knowledge of elementary meteorology.

Prof. C. W. Mathews, dean of the course in agriculture, has expressed a desire to have it taught in that course by at least a series of lectures and the writer has, to a limited extent, lectured before that class. (Mr. Dean has forwarded outlines of five lectures given, comprising the following subjects: Weather maps and forecasting, meteorological instruments, frost, clouds, air motions.)

Prof. R. N. Roarc has expressed a desire for students in the State Normal, of which he is principal, to obtain a knowledge of the use of maps, and encourages their use in the common schools.

B. C. Caldwell, president State Normal School, Natchitoches, La.:

There is no normal course in meteorology provided for in this institution, but by use of weather maps, meteorological reports and observations, and recording of weather data, some knowledge of meteorology is given throughout the entire course of study presented at the normal school.

O. L. Fassig, associate in meteorology, Johns Hopkins University, Baltimore, Md.:

The course in meteorology has been a gradual development since its introduction in 1897. It has all along formed part of the instruction in geology, having, however, distinct place and treatment. The course includes lectures twice weekly for one-third year.

> The topics chiefly to be considered are: Heat and its distribution over the earth's surface; rainfall and evaporation—their distribution and effects; winds and storms; weather sequences as illustrated by the daily weather charts of the United States Weather Bureau; extent to which topography influences the distribution of the climatic elements; variability of climates; organization and method in statistical meteorology. Special attention will be given this year to the consideration of the weather and climate of Baltimore and vicinity. (Extract, p. 13, Programme of Instruction in Geology for 1905.)

A very interesting course, and one having an important bearing on the furtherance of school work and instruction in meteorology, was the series of lectures that was delivered in 1899–1900. About 175 of the public school teachers of Baltimore city and county attended this course. The lectures were delivered in lecture halls of the Johns Hopkins University. They were systematically outlined, were variously illustrated by printed diagrams and charts, blackboard work, and lantern views, and numbered 20 in all. At the close of the series the local weather bureau office was visited by the teachers in groups of 8 to 10, and the instruments and work of the bureau were described.

George B. Wurtz, United States Weather Bureau, Escanaba, Mich.:

It is believed that meteorology would be a valuable addition to nearly every course in engineering, and also in medicine, where it has received only passing consideration; and my observation leads me to believe that it should be a part of the course prescribed for the issuance of papers to masters on the Great Lakes.

As a career, meteorology is believed to supply but a limited field, of which the Weather Bureau constitutes the principal portion. It is not known where commercial enterprises are depending upon the meteorologist, as such, for the aid that is secured to them from other professions, and it appears that the time has not yet come when the meteorologist is demanded distinctly for his attainments in the measure that the engineer and the chemist is sought. Commerce, agriculture, and the comfort of the general public are demanding and using the aid of meteorology, but not so much as a specialty as an augmentation of other professions.

J. W. Hubbard, department of geography, State Normal School, Duluth, Minn.:

The normal schools are particularly interested in the subject as a phase of geography. The extraordinary industrial and commercial development of the United States has brought the study of geography to the front rank of importance among common school studies, especially the physical side of it, without which there can be no intelligent study of industries or commerce. The proper understanding of meteorology lies at the basis of all physical geography phenomena, and in most schools the teachers are trying to do what they can, both by discussion and by practical observation of weather conditions, to have their pupils grasp some idea of the importance and scope of meteorology. But many, if not most, teachers are not well prepared to carry on the work properly because of lack of training on their own part. The efforts of the Weather Bureau to create an interest in the subject of meteorology by lectures and a display and description of its apparatus are most commendable. The specialist in this line, as in any other, is better prepared to speak upon the subject than anyone else. There should be some definite, organized system of lectures, extensive enough for the student to really know something of the principles and methods of investigation in this interesting field. I would heartily indorse such a course.

H. W. RICHARDSON, United States Weather Bureau, Duluth, Minn.:

In addition to occasional lectures of a popular character, the writer gave a rather systematic course of seven lectures to the normal school of Superior, Wis. The lectures were delivered weekly, and were one hour in length. The main lecture room of the Superior normal school was used, the audience on each occasion averaging close to 300 students. The subjects were as follows:

(1) The Weather Bureau; history, organization, duties, value.
(2) Meteorological apparatus; theory, construction, use.
(3) Circulation of the atmosphere; pressure, temperature, winds, precipitation.
(4) Cyclones, hurricanes, thunderstorms, tornadoes.
(5) Cold waves, warm waves, frost, dew, etc.
(6) Weather of the United States; especial reference to local climate.
(7) Weather maps, forecasts, warnings, miscellaneous reports; their use and value.

Local interest in connection with such lectures is most encouraging. Up to the present time official duties have prevented giving the matter the attention it deserves. The writer is quite sure the normal schools in Duluth and Superior would appreciate meteorological instruction regularly as regards their classes in physiography especially. Occasional special lectures would suffice in other local schools.

Prof. R. B. FULTON, chancellor University of Mississippi, University, Miss.:

Our location does not give now that close relationship with the United States Weather Bureau that seems to be a necessary stimulus to active study of meteorology as a science. Our funds for this purpose are limited. The only work in meteorology is that done by the professor of general physics. We have no special fund for meteorology.

A small portion of the time allotted to general physics in the sophomore and junior classes is given to the study of meteorology. This is practically an elective study. There is no specialization in it.

The special demand on the part of students is small. Twelve years ago, when this was the center of the volunteer weather service for the State, we had considerable interest. This university has given two valuable men to the service of the Weather Bureau, one of whom was trained here for the work twelve years ago.

I am sure that the lack of interest in meteorology as an applied sci ence is due very largely to the fact that not sufficient emphasis is laid on its importance and value in college courses.

The didactic value of meteorology is as great as that of any science. Like astronomy and geology, it calls for a general knowledge of all other physical sciences, and its generalities are a most valuable means for reviewing and applying knowledge of them.

The whole scheme of work done by the United States Weather Bureau is a most important lesson in applied science, as well as in observational methods, and a study of meteorology and its application furnishes fine opportunity to show the value and uses of scientific observation and investigation.

HOMER T. FULLER, president Drury College, Springfield, Mo.:

The lectures given to teachers last summer in our summer school by Mr. Hazen (Weather Bureau official) were valuable and interesting, and the further pursuance of the subject as a branch of general geological work is now being taken into consideration by us with respect to the future.

I believe that a scientific knowledge of this subject is becoming more and more valuable; that the demand for such a course in our colleges and universities is increasing; that the disciplinary value of the study, especially for the cultivation of the powers of observation, is great, and that the commercial or pecuniary value of the subject is of considerable importance.

I am decidedly of the opinion that a knowledge of this subject is necessary for civil or hydraulic engineers and that the work can only be adequately carried on in connection with a Weather Bureau station, and also where all the text and reference books available can be used for consultation. The subject is one of great importance, and I believe the time is coming when railway and land companies will find it to their advantage to employ trained meteorologists who probably have also specialized in chemistry and geology.

The following is the outline of the twelve weeks' course in meteorology given by Mr. John S. Hazen, United States Weather Bureau official at Springfield, Mo., before a class of teachers attending the Drury Summer School at Springfield in 1903:

Lesson 1.—Outline of course, with history and aim of Bureau.

Lesson 2.—Meteorological instruments in general use by Weather Bureau offices, with detailed description of same. Exhibition of instruments, with quiz by instructor. Ability of class to name and describe each.

Lesson 3.—Thermometry. Heat and methods of warming the air. Molecular theory, diffusion, radiation, etc. (Charts.)

Lesson 4.—Class work. Drawing isothermal lines. Rainfall charts. Comparison with annual. Figures given by instructor.

Lesson 5.—The weather map and forecasting. Methods of map making.

Lesson 6.—Climate and weather; distinction between. How climate is made by weather.

Lesson 7.—Winds; methods of measuring, variation, with altitude, cyclonic and anticyclonic, monsoons, etc.

Lesson 8.—Practice by class in drawing isotherms and isobars. Drill until class understands clearly what they are.

Lesson 9.—Precipitation, rain gages, rainfall, excessive, causes, distribution of.

Lesson 10.—General circulation *v.* secondary circulation, and their modifying influence on the climate of the United States. Types of climate in the United States.

Lesson 11.—Optical phenomena of the sky; charts, photographs, etc.

Lesson 12.—General review and quiz. Practice in map drawing.

From one hour to one and one-half hours were given to each lesson. Class consisted entirely of teachers or those who were fitting themselves for teaching in the Drury Summer School.

D. T. **Kizer**, teacher of natural science, Springfield Normal School and Business College, Springfield, Mo.:

The subject of meteorology is one which our students in classes in physical geography take up to some extent, and, although but limited attention can be given to it, I find much interest aroused. I find also that it is not only an incentive to investigation and thought—especially through the means of laboratory experiments—but is also valuable to them as teachers in district and secondary schools in the teaching of geography and physics.

I believe that the utility of a knowledge of the subject of meteorology is beginning to be more and more appreciated, as evinced by the greater interest in it, and that it would be of especial value to such industries as fishing and transportation, as also to the large landed interests, and, perhaps, even to the small farmer.

William R. Trowbridge, principal Helena High School, Helena, Mont.:

Aside from forming a part of a general course in physical geography, the subject is not taught in the Helena High School. About a month is given to meteorological questions, the platting of weather maps, and the recording of storms, cold waves, precipitation of moisture, etc. There is no demand specifically for such a course, probably because pupils of high school age do not know there is such a subject and would not know what it comprised if it were offered. The didactic value of such a course would be doubtful in my mind for the simple reason that the minds of pupils of that age are not matured enough to grasp the significance of the phenomena. It is hard enough to make them comprehend the simplest principles of atmospheric circulation, dew point, storm areas, etc. I have no data with reference to the pecuniary value of meteorology as a professional career.

J. P. **Rowe**, professor department of physics and geology, University of Montana, Missoula, Mont.:

The only work now offered along this line is in connection with physiography. This work is under my supervision, but several lectures on weather forecasting, etc., are given each year by Prof. M. J. Elrod. We hope within a year or two to offer a course, or courses, in meteorology, but at present we have neither the money nor the apparatus for such work.

The study of meteorology is undoubtedly beneficial, and from a didactic standpoint is far superior to many subjects now given in all college courses.

Additional notes by Professor Elrod:

The university is remote from Weather Bureau stations, Kalispell and Helena each being 125 miles distant. A voluntary observer's outfit is all there is in the city. The site is an admirable one for experiments in air currents above surface, as there is a 2,000-foot mountain immediately back of the university, which owns its summit.

The attention of students has not been called to the subject as a study, nor has it been brought to the attention of the authorities. The demand for such courses is small, due to lack of knowledge by students of the utility of such work.

I consider that the disciplinary value of the study, presented in a cientific way, with proper apparatus, is as great as for any of the ciences. It requires care, painstaking observation, skill, and "head work."

At present meteorology offers no chance to a young man as a proession, as I view it. If the demand for men existed, young men would take up the work.]

Samuel B. Doten, meteorologist, Nevada State University, Reno, ev.:

We provide no courses in meteorology, and there is as yet no demand or them on the part of our students. Our course in irrigation engieering should certainly include some work in meteorology.

It seems to me that, as a means of mental development, meteorology s much the same didactic value as any other branch of the science physics, and in addition its value as an enlightenment upon natural henomena of daily and hourly occurrence.

Edmund J. Vert, president New Mexico Normal University, Las egas, N. Mex.:

We have no course in our normal and academic department separate om physical geography. In our training school, however, which onsists of the first seven grades of city schools, we give a systematic ourse in meteorological observations from the first to the seventh rade, inclusive. This lays a good foundation for the more formal tudy of the subject in connection with physical geography. The subect of meteorology would rank with geography in its disciplinary alue.

J. D. Tinsley, soil physicist, department of soils and physics, New Mexico College of Agriculture and Mechanic Arts and Agricultural xperiment Station, Mesilla Park, N. Mex.:

The course here is offered more from the standpoint of information an from that of didactic value.

We have had no demand for work in meteorology in the past, and st year it was not taken as an elective by any student. There is no tra tuition for this work.

Since only 24 periods of fifty minutes each are given to this work, is only possible to give a very elementary idea of the subject.

C. M. Light, principal Normal School of New Mexico, Silver City, Mex.:

Our institution teaches the subject of meteorology throughout all grades of the training school and gives a course of five weeks of t-book work in the normal proper during the first year.

The value of a course in meteorology is the same as that which is derived from the study of any of nature's forms. It cultivates quickness of perception, stimulates a spirit of research, and is eminently practical. A curriculum would not be complete that would leave ou a course in meteorology, and I do not think any school does so. O course some schools make the course more extensive than others.

As to the pecuniary value of meteorology as a professional caree I think it must, for some time to come, be limited to the Governmen service. It will be a long time before public school systems, in m opinion, and especially secondary institutions, would be justifiable i giving a technical education along this line.

Charles R. Keyes, president New Mexico State School of Mines Socorro, N. Mex.:

The main facts are given in connection with the geological courses It is expected that a special course will soon be established extendin over two semesters. We consider the work very important and o special value in an engineering career.

W. H. Lemon, principal's office, State Normal School, Brockport N. Y.:

The instruction given in meteorology is part of the course in physical geography and covers about ten weeks. It is taught by lectur recitation, and laboratory work. The text is Davis' Elementar Meteorology. All take the subject who have not had physical geography before entering our school.

David Cuthbertson, United States Weather Bureau, Buffalo, N. Y

The secondary schools (public high schools and academic parochia schools) are the only institutions in Buffalo that teach meteorolog systematically. As a subdivision of physical geography, to whic twenty weeks are devoted, meteorology receives from four to fiv weeks of time (daily recitations), in which the work required and outlined by the regents of the University of the State of New York i completed. The subject-matter in the chapter on the atmosphere i any good, modern text-book of elementary physical geography, e. g. Tarr's, represents very well the work required by the regents. I addition to this, all schools give practical instruction in making complete weather maps from dictated data, many of them making systematic temperature and cloud observations, while the observations o some of them embrace maximum and minimum temperatures, dry-bulb and wet-bulb temperatures, barometric pressure, rainfall, win direction, and amount and kind of clouds, once or twice daily fo several weeks. These courses, as a rule, include an excursion to th Weather Bureau office, where all the instruments of the station an the practical workings of the Bureau are explained to the classes.

Charles L. Williams, Glens Falls, N. Y.:

The bureau of tests of the International Paper Company here ha use for knowledge of the subject, but the head of this bureau inform me that, in his opinion, there is not sufficient demand for trained meteorologists to warrant making the subject one of special work, either i the preparatory school or in college.

R. G. **Allen**, United States Weather Bureau, Cornell University, Ithaca, N. Y.:

Course No. 40, page 80, of the Announcement of Courses of Instruction, to be given at Cornell University during the year 1904–5, is as follows:

E. Meteorology.

40. *Meteorology.*—Three hours, second term. Two lectures and one period devoted to laboratory work and weather observations. The course is concerned with the temperature, rainfall, and other meteorologic elements, their normal conditions, variations, and distribution; with the general atmospheric circulation; the cyclonic and special storms. Students will be made acquainted with the weather map, forecasting, and the instruments used in measuring and recording meteorologic elements. Lectures Tuesday, Thursday, 11; Friday, 2 to 4.30. Mr. Hubbard.

This course is new and will probably be the most satisfactory one yet given at this university. Mr. Hubbard, who is to give this work, will be an instructor in geology, and this work will be incident to his regular duties as instructor in that department. Probably 15 to 20 students will take this subject.

A course was given last year by the writer, Waldo being used as the text-book. It was for agricultural students only, and was elective, only 8 taking it.

As to meteorology as a profession, the most efficient graduates of this university command larger salaries immediately after graduation than is paid an assistant observer when first appointed; thus the Bureau would not be able to obtain any considerable number of the more brilliant graduates of the agricultural and engineering classes, although there will be a number of students each year who would be glad of such appointment. As there is at present no other field for the meteorologist, I am of the opinion that the subject does not now appeal strongly to the students, as they are generally ambitious to become breadwinners, and in the beginning plan to prepare for the field that offers the largest rewards financially. I have discussed the subject with a number of students and I find that the initial salary is not sufficiently high to make it very attractive to a large number of those preparing for the journey through life. It is my opinion that assistant observers advanced from a lower grade are more efficient assistants on station than college graduates without experience in the Weather Bureau, although I see the need of higher education for the purposes of investigation and research.

William Hallock, professor of physics, Columbia University, New York, N. Y.:

There are no revenues at Columbia University available for the teaching of meteorology by itself, and if taught it would have to be in connection with some other subject, probably physics. It is not likely that there will in the near future be such a demand for instruction in meteorology as to justify the devotion to it of all the time of a qualified professor. There are no arrangements for a collection of fees in special subjects, and if the instruction were taken up it would necessarily be supported by endowment.

No courses are now given in meteorology. An optional course was offered for several years, but its election was so seldom that it was dropped. Some instruction in meteorology is given in connection with the courses in geography at Teachers College. It would no

doubt be very good for engineering students to have some knowled
of meteorology, but it is very uncertain in my mind whether such
course as could possibly be introduced into any of the present crowd
curricula would be worth while, and I believe that the same ti
devoted to some other subject might well prove more valuable.

During the past year one student asked for instruction in a f
facts concerning meteorology and meteorological instruments, b
only wished a few hours, and desired it only because he would
required to teach a little of it in connection with geography. T
demand was met by a few hours' work with me.

I have very serious misgivings as to the disciplinary value of t
study. Of course, if the student is required to make the records
may inculcate a certain amount of regularity, but I believe that c
of the more exact experimental sciences is preferable. Meteorolo
partakes too much of the purely observational character and its c
clusions are too uncertain. The factors involved are so numerous a
hard to determine that constant allowance must be made for unsu
ported conclusions and apologies for unverified predictions. It rea
is the most difficult science of them all, in its application. Of cou
it will later become utilitarian, even though taught for disciplina
purposes, because all knowledge is useful to us whether we realiz
or not. Students in law, geology, etc., would scarcely have more u
for meteorology than an ordinary citizen, but the physician or botan
should know something of the subject; but even in their case t
branch of climatology is really what they want.

H. L. Fairchild, department of geology, University of Rochest
Rochester, N. Y.:

The course in meteorology is given as part of the work in the depa
ment of geology. The course is three hours per week during the w
ter term. As text-book, Waldo's Meteorology is used but the wo
is partly by laboratory methods, with practical observations, study
cyclones, and individual prognostications. The course is elective
juniors and seniors. It is the judgment of the writer that the stu
should be a requirement for all civil engineers.

There was no demand here until the course was offered. The dis
plinary value of the study is the same as that of any observatio
science. The work here is intended as cultural.

Regarding the opportunities of following meteorology as a prof
sion, I have no special knowledge or opinion. It would seem as if
should become of vast practical importance in affairs of life and
made prominent in courses of university study.

L. W. Crane, superintendent board of education, high scho
Rome, N. Y.:

Meteorology is not taught in our high school, except as it comes
as a part of physical geography. We have done some work in
grades in an elementary way, for the purpose of leading the pupils
observe natural phenomena, to give them definite standards, to int
pret climatic conditions in other regions, and to develop appreciati
of the influence upon life conditions. While the work has not b
unified, I hope that during the coming year a somewhat system
course will be laid out. Such work not only has disciplinary va
but also subject value, in my judgment.

J. H. **Willets**, superintendent of schools, Troy, N. Y.:

The subject of meteorology is taught incidentally in our high school and very lightly touched upon in some of the grades. There is no doubt that it possesses some didactic value, but to what extent it would be difficult to determine.

Meteorology is certainly a very interesting study and must be of value as a means of discipline. Its utilitarian value is, of course, problematical, but it is only fair and reasonable to suppose that in time it will rank with many other sciences in this respect.

Henry Louis Smith, president Davidson College, Davidson, N. C.:

I write to say that Davidson established a three months' course in meteorology in connection with the regular course of astronomy at least ten years ago, and has taught it continuously ever since. As to the character of the course, it is an elective study, belonging primarily to the senior class, but open to juniors. It is combined with astronomy as part of the course, although taught, of course, from a different text-book. The course has proven quite popular. The class is numbering between 20 and 30 each year.

In my own information, the didactic value of meteorology is very great. It opens to the ordinary citizen a branch of scientific study and investigation which touches his life every day, and is of great practical interest as well as being easy of investigation. For the ordinary citizen it has commercial and pecuniary value, yet I agree with your circular that as a preparatory training for many special forms of engineering it has great commercial value.

C. F. **von Herrmann**, United States Weather Bureau, Raleigh, N. C.:

The Agricultural and Mechanical College, located at West Raleigh, has for several years given a course of instruction in meterology. There have never been any special revenues available for this work, which has been conducted by the teacher in agriculture as an incidental in the course in agriculture. Only a small portion of the teacher's time was given to this course. Formerly, instruction was given in meterology by Prof. Benjamin Irby, professor of agriculture, using R. H. Scott's Elementary Meterology as a text-book. Recitations were held once a week, and the course was supplemented by lectures delivered at the weather bureau by the writer, the class being brought into the office for the purpose of gaining an insight into the practical work of the Weather Bureau and an understanding of the instruments used.

Professor Irby's successor, Prof. Charles W. Burkett, allowed the work to lapse for a time, but in 1903, just before the beginning of the school year, he requested the Secretary of Agriculture to detail an instructor in meteorology, and the writer took charge of the course. Owing to the fact that the appointment was made just at the beginning of the school year, there was not sufficient time to prepare a complete course of lectures, so that it was decided to use Waldo's Elementary Meteorology as a text-book. Before the arrival of the book, however, two preliminary lectures were delivered. During 1903–4 the course was given only to the senior class in agriculture; it continued throughout the year, recitations being held each Monday from 1 p. m. to 2 p. m. The work was very largely supplemented by lectures in explanation of the text. The course was considered a minor but required subject for the students in agriculture. In 1904–5 the course will probably consist entirely of lectures.

In my opinion Waldo's Meteorology is unsatisfactory as a text-book. My lectures were based largely upon the German text of Hann (Lehrbuch der Meteorologie, 1901).

J. WARREN SMITH, United States Weather Bureau office. Columbus, Ohio:

Upon receipt of the circular from the convention committee relative to this matter a letter was sent to 44 colleges and universities in Ohio.

Replies have been received from but a few. These show that meteorology is taught as a distinct subject at the Ohio State University, Columbus; Heidelberg University, Tiffin; Buchtel College, Akron, and Muskingum College, New Concord. It is taught in connection with physical geography at Dennison University, Granville, but will be taken up as a distinct study next year.

The Ohio State University is the only one located in a city where there is a Weather Bureau office, and the only one with an official of the Bureau as instructor.

At Heidelberg University and Muskingum College, meteorology is taught as a branch of the department of natural sciences. At Buchtel College the course is given by the professor of mathematics and astronomy.

At the Ohio State University we give two hours a week during the spring term of ten weeks. The work is required in the junior year in the college of agriculture and domestic science and is elective in the college of arts, philosophy, and science.

We used Davis' Elementary Meteorology the first two years and prefer it to any other, but it is too large a work to cover in 20 lectures. We now use Waldo's Elementary Meteorology and the daily weather maps. The time is fairly divided between lectures (three of the lectures are illustrated with lantern slides), recitations, and laboratory work. Drill is given in map making and the use of instruments. One of the lectures is given at the Weather Bureau office, explaining the instruments and the work of the station in detail.

I make the keeping of the daily journal of the weather one of the strongest requirements of the course, and believe that it is very profitable. The journal covers observations upon the advance of vegetation as well as upon the weather. The daily weather maps are studied systematically, and an attempt is made to correlate the weather that has been experienced at Columbus or other places in the country since the last recitation, with the conditions shown on the maps.

I consider the daily weather maps to be essential to a proper understanding of the relation between pressure and wind direction, wind direction and temperature, etc. Also that the actual work of charting the pressure and temperature figures and tracing the isobars and isotherms gives the student an understanding of pressure and temperature maps that he can acquire in no other way.

The actual class work may be termed elementary, but we bring in enough mathematics and physics to lay the foundation for and incite an interest in further study if the student be so disposed. In other words, an effort is made to have the student look at the changing weather conditions from a scientific point of view rather than from the dark or the light of the moon.

The Weather Bureau, its history, and its methods of collecting and distributing information are carefully shown and the basis of the forecasts and warnings explained.

The text-book is unsatisfactory and must constantly be supplemented by outside reading. The main reference books are Davis' Elementary Meteorology, the Monthly Weather Review, and Bartholomew's Physical Atlas.

The Muskingum college requires of each freshman who is a candidate for the degree of bachelor of science one term. Waldo's Meteorology is used, with such practical work as the study of the weather maps, charts, reports, etc. The teaching is by recitation, when every effort is made to render the subject practical. Prof. A. H. Wright, who gives the course, states that the text-book is not satisfactory and that they wish to use Davis' text next year.

Prof. M. E. Kleckner, of the department of natural sciences, of Heidelberg University, writes that they do text-book work, supplemented with lectures, no time being at his disposal for carrying on laboratory work. They devote the third term of the senior year to the subject and all students in the scientific course are required to take it. For others it is elective. Waldo's elementary work is the text-book.

At Buchtel College the course in meteorology has been taught by the professor of mathematics and astronomy. Prof. H. V. Egbert started the course, but it is now taught by Prof. F. M. Morrison, his successor. The course has been elective, running four hours per week for four and one-half months. Any student above the freshman year may take it. It has been text-book work, supplemented by various articles. Waldo's text has been used, but the present instructor states it is so elementary that it is unsatisfactory. He thinks that Davis' would be better, but that with the use of either text-book recent articles are badly needed, so that the work may be kept up to date. He finds it very hard to get hold of the material that is needed.

At the Ohio State University the number taking the course during the past five years has varied from fifteen to forty. It has been elected by some students from the college of engineering, by teachers of physical geography in the Columbus public schools, by some of the faculty of the university, and by special students as a preparation for the "observer" examination.

At Heidelberg half of the students, not scientific, elect the subject, some on account of the educational value and others for information.

The class at the Muskingum college had 27 members last year.

The few other educational institutions in Ohio from which letters were received state that there has been no demand for the course. The president of the Case School of Applied Science at Cleveland states, however, that they would be very glad to have the study given in connection with their physics course, which is intended to prepare students for teaching. He thinks that with their regular mathematics and sciences a number of such courses could be introduced to great advantage.

The feeling seems to prevail on the part of some that educational institutions will not precede the demand. There are so many courses already established that they will wait for the students to request the work, or at least until there is a demand for trained meteorologists. While this may be true of some of the more conservative, we believe that the more progressive universities and colleges recognize th with the professions crowded as they are and with business competiti as strong as it is, they must take the initiative in suggesting n fields of effort and in assisting the student to take advantage of eve possible aid to specializing.

Theoretically, the opinion seems to prevail that the subject is of gre value for training the mind, if well taught. Some of the express opinions are interesting.

Professor Jewett, of Oberlin:

> My feeling is that it might be made a very profitable study in the hands of thoroughly competent teacher.

President Hunt, of Dennison:

> I see no reason why the didactic value of meteorology should not be as great any other scientific study if taught equally well.

President Howe, of Case:

> Should think it might be of great didactic value if proper text-book and meth were used.

Professor Wright, of Muskingum:

> The study will train the power of observation.

Professor Pettee, of New Hampshire:

> Few subjects are better adapted to such purpose.

Professor Davis, of Harvard:

> Excellent, if well taught.

Practically, I will quote from letters from some of the former st dents who have taken the course at the Ohio State University and ar now engaged in educational or other pursuits in various places.

Professor Miller, Missouri State College:

> As a means of developing the powers of observation it is undoubtedly of muc value, and this, together with the fact that it is possible for the student to follow th subject continuously from day to day, adds much to its importance.

Mr. Ruhlin, Grand Cane, La.:

> The study was of as much value to me as a mental trainer as any of the other sciences. It aids one to become a better observer, especially of the influence of weather changes upon the growth of vegetation, the daily journal being a great help in this respect.

Mr. Adams, Independence, Kans.:

> As a disciplinary study, first class, as it deals with many everyday affairs that are commonly overlooked. The writing of the daily journal trains the observational faculty.

Professor Bownocker, of Ohio State University:

> It is a valuable study and furnishes discipline of a high order. Especially is this true when it involves laboratory work. In my judgment it is superior in this respect to some branches which now occupy an important place in our curricula.

Mr. Sanders, Chillicothe, Ohio.

> I consider its didactic value to be of high grade, comprising as it does the practical application of several studies of known worth to the acquisition of new knowledge.

Professor McCall, Ohio State University:

> The daily practice of making individual weather observations and correlating these observations with passing events is in itself valuable practice.

Professor Hayden, University of Illinois:

It is surely a good mental trainer and teaches one to observe. It was of as much value to me as any other study pursued for like time.

Mr. Coberly, Columbus, Ohio.

In my opinion its value is fully as great as any of the natural sciences and greater than many of them. The training in writing the daily journal has been of great value to me.

Professor Jennings, Pittsburg, Pa.:

As to the training afforded by the study of meteorology, I would place the branch very high, especially as regards observation and reasoning from cause to effect. I can unhesitatingly say that I am a better observer of natural conditions and can refer certain botanical phenomena to causes much more accurately than if I had never studied meteorology.

Mr. Snyder, Washington, D. C.:

With regard to the value of meteorology as a course of mental training, I consider t of first rank. It furnishes ample means for the development of the reasoning culties, excellent training of the memory, and probably cultivates the powers of bservation more than any other branch.

Professor Taylor, New Hampshire College:

The daily journal, if properly kept, is very valuable, because it teaches the student lose habits of observation, and this is a fundamental object of his college training.

As to the commercial or pecuniary value of the subject, we judge of he value of a study by its results, and I quote again from the letters eceived from men who have taken the course in this subject at Ohio tate University.

Letters were received from one professor of agriculture; two who re employed in the Bureau of Soils; one truck farmer; one fruit rower; one professor of geology; two professors of agronomy; one resident of a college; one professor in botany; one farmer; one Veather Bureau observer; one instructor in dairy husbandry, and ne clerk in a life insurance office.

The last two could not see that the course was of any present pecuniary benefit to them. Some of the other statements are quite valuable:

I can say that the knowledge of meteorology is of much value to me in my work n agronomy, and I am convinced that there are many other lines in which this nowledge would be of great importance. I also believe that many commercial nterprises are much more dependent upon meteorological conditions than is generlly supposed, and that we shall not reach our most economical basis of commercial roduction and enterprise until greater cognizance is taken of weather conditions as ffecting both employers and employees, as well as the products or materials conerned. (Professor Miller.)

I should consider myself much handicapped in my profession (fruit grower) without some knowledge of meteorology. (Mr. Sanders.)

It seems to me that meteorology should be taught in all agricultural courses as well s in engineering courses, and probably it should be made elective in all of the other ourses offered in our land-grant colleges. (President Gibbs.)

I can say that my knowledge of meteorology, gained at Ohio State University, has een of great practical benefit and value to me in the Bureau of Soils. A knowldge of meteorology is certainly a valuable asset to any employee of any company ngaged in vast commercial enterprises. (Mr. McCall.)

I consider the term's work at Ohio State University of practical value to me, and ere I just entering on a college course I should want meteorology, though I should ay one year instead of one term. (Mr. Ditto, of Delphos.)

It is my opinion that the time will come when all large enterprises, such as railoads and transportation lines generally, will have their trained meteorologists, just many of them are now getting their trained foresters. (Mr. Coberly.)

Probably no other department of natural science is so intimately connected wit botanical work, and as an auxiliary study I regard meteorology as one of the mo interesting and valuable branches I have ever taken up. (Professor Jennings.)

It has often occurred to me that the small amount of time which I spent upon th course has yielded better returns than an equal amount of time spent upon any oth branch. (Mr. Snyder.)

The information that I gained from my college course in meteorology has been no little value to me in my present instructional work. It is my opinion that, wit the constantly increasing body of knowledge relative to the science, the time is n far distant when many of our large commercial enterprises will require the servic of specialists and experts along meteorological lines. (Professor Taylor.)

These extracts seem to show conclusively the wide range to whic the subject can adapt itself.

President Thompson, of Ohio State University, says:

My impression is that the training in this subject would be a valuable portion a man's equipment in a business way.

President Hunt, of Dennison, adds:

The study would, of course, be of commercial value in connection with agricultu and some other lines of private business. It is quite probable that the wider stud of the science would discover many more practical uses for it.

There is a gentleman living in Columbus who has had a wide exp rience in Weather Bureau work and is now filling an important pos tion with a natural-gas company. His practical knowledge of meteor ology has enabled him to work out a table of the consumption of ga under varying temperature conditions, so that months ahead he ca make preparations, not only for the regular supply of gas, but for th additional amount that will be necessary should there be a week or month of as cold weather as has ever been experienced. His com pany supplies much of the northeastern quarter of the State.

A baker came to my office one day to get some assistance in hi bread making. He found that on some days his dough raised muc more rapidly and completely, and so made better bread, than on other days. He thought the problem was one of pressure and wanted t know where to secure a barometer. I advised him to get a sling psy chrometer instead, and if he finds, as I think he will, that it is the rela tive humidity of the atmosphere that affects the action of the yeast, h has a condition that can be very easily controlled and a knowledge tha must prove very profitable.

The bacteriologist of the Ohio State board of health has been making experiments on the value of different disinfectants, and has discovered that no disinfectant now in use is really effective one day in a hundred with the conditions of relative humidity that prevail in the average house, especially in winter time, a much higher percentage of humidity being necessary.

The superintendent of construction of a railroad in my city has learned from experience that the load of a locomotive must be reduced as the temperature lowers, irrespective of the other atmospheric conditions. If the temperature is above 40° so many cars, reducing the load for each 10° less, until in most cases only about half as much can be hauled with the temperature at from 10° to 20° below zero as at 40° above.

Weather Bureau men, in large cities at least, know how regularly the produce men call the office before making shipments of perishable products, and I think they will agree with me in the statement that not one in a dozen, of the employees at least, have any idea of the temperature at which it is safe to ship their different articles.

A physician will treat a consumptive for weeks and months, until ere is little possible chance for recovery, and then send him away to me other climate to die. Yet if he had a real knowledge of meteor- gy or climatology he would know that the air of one place is just good as the air of another, if he will only insist that the patient, en the disease first begins to be apparent, gets air and not dust and t and carbonic acid. Last year I had the pleasure of serving on a te board that succeeded in convincing a legislature and governor of truth, and an appropriation was made for a tuberculosis sani- ium in Ohio, where a patient in the early stages of the disease can for treatment.

he article upon the relation of rainfall to corn yield in the last Year- k by Professor Gibbs and myself, and the studies that I have pre- ted upon the relation of weather to crop yield in Fulton County, io, convince me that there is an unlimited field for trained meteor- gists in working out crop-yield problems, and that the transportation panies or produce dealers that are the first to set experts at work ng this line will reap the results.

he duty of educational institutions is not only to teach, but to ise, to direct, and to search out the opportunities for the student specialize.

en or fifteen years ago few students, even in our agricultural col- es, took the course in agriculture who could take anything else. t at the present time one sees what a science such men as Hopkins Illinois, Hunt of Cornell, Doctor True, Professor Whitney, and our n Secretary are making of agriculture. They have demonstrated t there is nothing that requires closer study, a keener mind, a finer ucation, than the study of the soil, and nothing else in which a busi- sslike application of scientific knowledge will produce quicker and ger results.

So it will be, we believe, with the study of meteorology. No scien- ic college curriculum will be considered complete without it, the ff of no extensive business organization will be without an expert ong its members, and every progressive business man, whether in e store or upon the farm, will feel that he must have some under- nding of the laws of the atmosphere and the ability to interpret its oblems.

What, indeed, is the study of meteorology but a study of astronomy, mathematics, of physics in all its branches of light, heat, and elec- icity, of chemistry, of agriculture, of all the sciences combined and lled into one, of very life itself.

Prof. George H. Twiss, of Columbus, puts it very neatly. He says e should not say "earth to earth," etc., but should say "air to air, r of the air we are made and to the air we finally return."

H. W. Harmon, department of science, South-Western State Nor- al School, California, Pa.

Our work here at the Normal in meteorology is not a separate urse, but it has been introduced as a part of the laboratory work in e subject of physics. At the beginning of the fall term five or six tern-slide lectures are given. The various instruments are thrown the screen and their principle and construction explained. The truments are assigned as lesson topics, and each student hands in a gram with description and explanation of use. Other lantern slides are of weather maps, showing typical storm centers and paths, cold waves, hot waves, and the relation between rain and snowfall and river rises and floods. The theory of storms is presented in a simple way. Following these lectures the class is divided into groups of four students each. These groups take all of the observations for a week during a warm-weather month, and later, for a week during cold weather. The factors observed are, rainfall; maximum and minimum temperature; the sling hygrometer is used to obtain dew point and percentage of moisture, and the hair hygrometer readings are made for the same purpose; wind direction and velocity from the cup anemometer; barometer readings (mercurial and aneroid); clouds, with kind and direction of movement; and miscellaneous phenomena.

From these data and the weather maps received daily the student group make their prediction of weather for the next twelve hours. The further written work is the weather thesis, the topic "Weather" in general being the subject. This thesis includes, besides the previous report on instruments, quite an extended essay on weather and storms, a tabulated form of the month's data, a careful analysis of the same, and the drawing of the curves of barometer change, mean temperature, and dew-point. These curves are studied to find out the existing relations between the several factors. Curves of rainfall and of river changes are also plotted and studied. After the week of cold weather observation is finished, similar curves are drawn and a comparison is made between cold and warm weather conditions.

The object of the work is to gain useful knowledge of weather phenomena, to cultivate skill in handling delicate and accurate instruments, to train the mind to detect relations between dependent phenomena, and to make the students close observers of nature. All of this training, we believe, will better fit our students to go into the public schools as teachers, which most of our normal students are planning to do.

During the last three or four years, in which this weather course has been in application, the students have been more than enthusiastic over the results of the training. In all of the grades of our model school more or less weather work is being done. In the February (1903) number of School Science is a fairly complete outline of our weather work here. Also in the Scientific American Supplement, May 14, 1904, is a description of our wind vane and cup anemometer adapted to school use.

J. Gordon Ogden, Pittsburg high schools, Pittsburg, Pa.:

The immense importance of the weather service in a utilitarian sense alone, apart from its scientific aspects, should be brought prominently before the public. There is no doubt but that the work of the Weather Bureau is in its infancy as yet. In order that it may be given the nourishment, encouragement, and assistance that it needs for a healthful growth, the great mass of the people have to be taught, first, that it is based on scientific principles and good common sense; second, that it is not a comic-opera department of our Government; third, that it is eminently practical in its theories and its functions; fourth, that it has saved invaluable lives and millions of property to the commonwealth; fifth, that its usefulness may be infinitely increased; sixth, that the ignorance of the ordinary citizen of its aims and methods is its greatest enemy.

Education is the keynote of the circular before me, but I would go rther than the secretary of the committee suggests. Why limit the eteorological work outlined to the "universities and higher technical stitutions?" Why not make a vigorous attempt to introduce it into very high school of the leading cities and towns of the nation? Why t get up a simple manual containing and embodying the essentials the subject, written in text-book style, with abundant and excellent ustrations (some of which I have seen in late Weather Bureau publi- tions), references, questions, reviews, etc., for distribution to such ools as will use them in the last high-school year? Also, why not epare and distribute sets of elementary apparatus, for use in such rk, to be loaned to such high schools as will make use of them, thus ablishing school stations, where the observers are to be students, d whose reports may be sent to the local weather bureau, or to some e directly in charge of this work at Washington?

I have been giving much attention to the teaching of meteorology ring the past ten years in my high-school work, and have found it t only a great pleasure to myself but also of considerable value to e pupils. I consider it a subject with a remarkable value as a mental cipline, in addition to its other valuable features. My work has en entirely normal—the training of teachers—and I have acted on e theory that every teacher in our public schools should thoroughly derstand the elements of meteorology in order to give the founda- n of science to the pupils over which they may have supervision.

I have found that the teachers I have so taught took an intense terest in the entire subject, as must have been observed on the occa- ns of our visits to the station in Pittsburg. Fieldwork in this department was of especial interest to them, and I know that those of my pils who are now teaching (and there are over 400 in Pittsburg ne) are using to advantage the information they thus acquired. e establishment of such practical work in the high schools need not terfere in the slightest degree with the excellent suggestion of the cretary of the committee concerning the work in universities and her institutions. Let these latter attend to technical training, math- atically and otherwise, of those who are to make the weather service eir profession. The high school will do a thousand times more than e university in popularizing the subject and educating the people ng this line.

L. N. Jesunofsky, United States Weather Bureau, Charleston, S. C.:

The College of Charleston is the only institution in this locality that s provided a short course in meteorology. The course was begun 1902, through the efforts of Prof. Walter H. Ashley. At the begin- ng of the season in 1903 Prof. Henry B. Ray took up the subject ere Professor Ashley left it unfinished in 1902, and he has since rsued the subject with gratifying success and results among the dents. The college is located but a short distance from the local ice of the Weather Bureau. No revenues or endowments are avail- le for maintaining the courses. Prof. H. B. Ray, instructor in ysics, botany, and geology, devotes one hour each week to the sub- t incidental to the study of physics, botany, and geology among the iors and seniors. It is also a minor study in connection with the gree of bachelor of science. The manner of teaching is by lectures, citations, and essays. The reference works are Davis, Loomis, and aldo, and are considered adequate and satisfactory by the faculty.

The value of meteorology as a disciplinary study is twofold: First, it makes the student quite familiar with the mechanical construction of the instrumental outfit of the Weather Bureau; and secondly, the knowledge thus gained, even though it be somewhat vague, owing to the short time devoted thereto, opens wide avenues of research into other fields where an understanding of meteorology is highly essential.

S. W. GLENN, United States Weather Bureau, Huron, S. Dak.:

In three of the higher institutions of learning in the State, viz, the State Agricultural College at Brookings, the State University at Vermilion, and the Northern State Normal and Industrial School at Aberdeen, meteorology is given cônsiderable attention.

In the agricultural college it is required of all students in the courses in scientific agriculture and agricultural engineering. There are three recitations per week during the spring term of the senior year. The subject is taught by Prof. E. C. Chilcott, vice-director of the experiment station and agriculturist, by means of lectures, examination and study of Weather Bureau charts and maps, and practical use of meteorological instruments.

At the State University the text-book used is Dryer, the subject of meteorology being taught by the professor of geology only as incident to physiography, and not in relation to any future career of the student.

The following is the catalogue statement of the required course in meteorology given in the Latin and English courses of the Northern State Normal and Industrial School. The work is in charge of Prof. Willis E. Johnson, Ph. B.:

> In meteorology the general properties of the atmospheric envelope are studied and a careful examination is made of areas of high and of low pressure, isobaric and isothermic charts being constructed by students from data obtained from the United States Weather Bureau. In a similar manner data are obtained from which a complete weather map is made by each student. In addition to a study of wind zones, cyclones, and anticyclones, some special attention is given to the tornado and Chinook winds.

The course occupies two daily periods for a term of nine weeks, is given in the junior year of the English course and the sophomore year of the Latin course, and is an integral part of a year's work in geography. The text used is Dryer's Physical Geography, but reference books are used more than the text, Davis and Waldo being most frequently used. The files of the Monthly Weather Review are used almost daily, and the Washington and Minneapolis weather maps and the Huron bulletin are used daily in class.

The independent construction of a weather map on blank forms, the use of hygrometer tables, the application of corrections to barometer readings, the plotting of temperature and precipitation curves for the State and locality, familiarity with the instruments, terms, and literature of the subject, and a knowledge of climatic conditions of various portions of the globe are all deemed of vital importance to the student of this subject.

The function of this institution is largely to train teachers, and it is believed that a rational conception of the weather and of climate and of the foregoing facts is an essential part of the preparation of a person to teach.

In the three high schools in the State that report work in meteorology, only that portion included in text-books on physical geography nd ordinary physics is given attention. There appears to be no emand for a separate course in the study, though the majority consider that it would be of value and is desirable. In no case has a lack f funds or of competent teachers been given as a cause of the absence f a course in meteorology.

WESTON M. FULTON, United States Weather Bureau (also instructor n meteorology at the university), University of Tennessee, Knoxville, enn.:

The Weather Bureau office here is located in one of the buildings of e University of Tennessee. The university revenues for maintaining e meteorological instruction here come from endowments. The riter has been instructor in meteorology at this institution since nuary 1, 1899, and has given the only instruction in meteorology at has ever been offered by the institution. His teaching has been cidental to his regular duties as official in charge of the local Weather reau office. The time regularly spent in the class room has been ree hours per week, but, of course, much more time than this has en spent in preparing lectures, correcting exercises (written), and preparing and delivering public lectures generally throughout the ate.

The object has been to make the course more thorough each year. e first year it was necessarily somewhat superficial, but during the st two years it has been quite thorough. As already stated, the course study continues throughout one whole academic year of three rms, with class periods of one hour each, three times per week. An tline of the course is inclosed herewith. The subject has always en scheduled for the junior year, and fully 90 per cent of the members of the class were juniors; the remaining 10 per cent were sophoores. No freshmen have ever been admitted. The subject has ways been elective for all courses. It is my opinion that meteorolgy should, in certain cases, be accepted as a major study for the gree of civil engineer or bachelor of agriculture. The subject has en taught by recitation, lecture, and laboratory work. I have btained the best results by having a text-book to be read by the ass, and employing lectures and laboratory exercises to explain and nplify the text. It seems to me that one of the greatest needs along is line is a good text-book. I have gotten the most satisfaction out f Davis' Elementary Meteorology, but all of the text-books now vailable are entirely too elementary. Meteorology is not an exact ience in the same sense that some of the older branches of science, ch as mathematics and astronomy, are; but it is far more exact than e present text-books would indicate, and a text-book making much eer use of mathematics and applied physics would be a great aid to e teacher.

There was practically no demand for instruction in this subject when e course was first offered in 1899. Since that time, however, there as been a steadily increasing demand. As nearly as I have been able judge, the students have selected the subject because they consided a knowledge of meteorology more valuable than a knowledge of her subjects from which they were allowed to make a selection. bout 10 per cent of the students in the university have, during the st two years, made application for instruction in meteorology, and out 80 per cent of the junior class have taken the course. The

demand has not been fully met owing to the fact that students ha
been required to take other work in order to obtain their coll
degrees, and in this way have not been allowed to follow up th
desire to study meteorology. Some students have included the cou
in their postgraduate work. Comparatively few, however, can aff
a postgraduate course.

If the subject is properly taught, it should certainly rank first amo
purely disciplinary studies.

It would seem that meteorology should be of advantage to stude
as a professsion, or at least as a valuable aid to success in certain li
of work. Several students who have taken the course of study h
have since reported that they were engaged in agriculture, and t
they found their knowledge of meteorology invaluable. Four of
students have passed the United States civil-service examination
entered the Weather Bureau as observers. The writer himself
recently obtained a furlough from the Weather Bureau for one y
for the purpose of taking charge of experiments for some local ma
facturers for the purpose of perfecting improved apparatus for h
regulation, etc. These manufacturers have experienced great diffic
in obtaining the services of anyone sufficiently grounded in a knowle
of air currents, the radiation and absorption of heat by gases, the r
tion of climatic conditions to artificial heating and ventilation, etc.
take charge of their work. There is undoubtedly a demand for yo
men possessing such knowledge.

The following is the outline of the course given, as inclosed with
report:

1. Elementary meteorology: Physical principles outlined; astronomical relati
sources of heat; distribution of insolation over the earth; temperature gradie
Conditions of local convection in the atmosphere; colors of the sky. (Text-b
Davis' Elementary Meteorology.) Illustrated lectures, recitations and labora
work. Same for both courses. Fall. Three hours, Tuesday, Thursday, Satur
12:15.

2. General meteorology: Academic. Thermometry; temperature normals;
thermal charts; measurement and distribution of atmospheric pressure; barome
isobaric surfaces; barometric charts. Anemometry; cyclonic storms and wi
local storms. Illustrated lectures, recitations and laboratory work. Winter. T
hours, Tuesday, Thursday, Saturday, 12.15.

3. General meteorology: Agricultural and engineering. Thermometry; soil
peratures; methods of computing means and normals. Dynamic meteorology; bar
etry; the laws of storms; atmospheric dust; rainfall, and its relations to soils, pla
and general agriculture. Frost formation and methods of protection. Illustr
lectures, recitations, and laboratory work. Winter. Three hours (selected to
class.)

4. General meteorology continued. Academic. Moisture in the atmosphere;
ous forms of precipitation; causes and distribution of rainfall. Weather and wea
forecasting; atmospheric electricity. Climatology; climate and health. Relatio
meteorology to the arts and manufactures. Illustrated lectures, recitations, and
oratory work. Spring. Three hours, Tuesday, Thursday, Saturday, 12.15.

5. General meteorology continued. Agricultural and engineering. Climatol
relation of climate to plant distribution; relation to mechanical structures. W
supply and storage; the flow of rivers; gauging of rivers and tides; use of windm
climate and manufacturing industries; engineering problems in meteorology;
tion of climate to dairying, stock breeding, pasturage, etc. Illustrated lectures,
tations, and laboratory work. Spring. Three hours.

W. S. **Carter**, dean, medical department, University of Te
Galveston, Tex.:

The course in climatology which is given to our medical student
this school is outlined on page 35 of our catalogue. Of course th
directed to bear upon the influence of climate on health and on

nditions of climate which may influence the conditions of patients in seased states. We make no attempt to teach meteorology as a pure ience. In regard to the course of instruction in meteorology which ould be given, I feel that the president of this university should press his views rather than that any such opinions should come from e. If such a course of instruction should be given in the University Texas, it should be given with the science and engineering course at ustin and not with the technical training which is given in the medl department of the University of Texas. As you have asked for y opinion, I must say that I question whether or not there would be ny to pursue such a course even if such were offered by our univeries. The matter of demand usually regulates the supply in any line technical training. I fancy there are few opportunities for men to rn a livelihood in this work, and there are few students in the colges who would elect such a course. Personally I feel that the oppornities offered in the study of meteorology as a professional career e very limited.

In regard to the didactic value as a study, I do not think the traing would be as valuable as, for instance, chemistry, because the readth is not so great and the sphere in which this knowledge can be plied is comparatively limited. Of course, if such a course is given should be thoroughly practical, and it seems to me that a considerale amount of instruction in this subject could be given to advantage s an elective in the course in science and the course in engineering our universities. Much of it could doubtless be taught by those eaching physics or chemistry or different branches of engineering, nd the handling of instruments of precision is always a profitable raining.

The following is the course in medical climatology at the department of medicine, University of Texas, as described on pages 35 and 36 of the catalogue:

Medical climatology (*James J. Terrill, M. D., lecturer on climatology*).—In this course instruction is given by systematic lectures, three times a week during the second third of the term, to the fourth-year students.

Every practitioner will be better qualified to accomplish the important work devolving upon the profession by acquiring a knowledge of the varying conditions and the many changes that take place in the atmosphere, which make climate so different in various localities in its relations to pathology.

The course of lectures embraces briefly a description of instruments and methods used in determining climatic conditions and changes; the origin of the atmosphere, its evolution, composition, and offices, together with its extent and spherical arrangement; the control of atmospheric temperatures—radiation, insolation, absorption, transmission, conduction, and reflection, with particular reference to the manner in which local conditions influence these in making differences in climate; the distribution of temperatures over land and water; the pressure and general wind movements and the ways in which they influence general and local climate; the moisture of the atmosphere, absolute and relative humidity, and sensible temperature of the atmosphere; clouds and sunshine, and their distribution; the causes of distribution of precipitation; weather and the control of weather changes, with generalizations as to weather forecasting. Then is taken up the manner in which weather changes and different conditions of climate influence the physiological functions of different organs of the body; the divisions of climates based upon these effects into "low, damp, warm climate," "low, damp, cold climate," "high, dry climate," and intermediate grades; the mineral springs; topographic features and distribution of climate in the United States, and the relation of climate to pathology and its influence in the distribution of the more important classes of diseases.

Charts and diagrams are used where practicable to illustrate the more important features of the lectures.

C. H. **Gordon**, acting professor of geology, University of Washington, Seattle, Wash.:

The work here is given as a part of the course in physiography o advanced physical geography. The full course is a year's work, divide up into meteorology, oceanography, and physiography. The meteo ology is accorded about four months of the time. Heretofore it ha been a two hours' course, but this has been wholly inadequate, and i the new catalogue about to be issued it is given four hours. It has n special recognition, but is offered as one of the courses in the departme of geology.

For all courses except that of geology and mining the subject i purely elective. It is my opinion that it should be a major subject i courses leading to engineering degrees, especially mining and irrig tion or hydraulic engineers. Instruction is given by a combination o lecture, recitation, and laboratory work. Waldo's Elementary Met orology is used as a text. The library contains additional books, b more are needed. The text is fairly satisfactory. As yet the subje does not seem to have reached a stage of development which mak the work done in it compare favorably with that in other science While I consider that potentially its educational value is great, the yet remains much to be done in the arrangement of text and materi to make available the present knowledge of the subject, as well as i the systematic development of the subject itself. The subject offe opportunity for much practical work, but more and better laborator manuals are needed, especially for schools where the instructor is co pelled to teach it in connection with other subjects.

The demand for the course is comparatively light. The number th take the work does not usually exceed twelve. This year it has bee very small, owing to the absence of the regular professor. Outside o the students in the geology and mining course, where it is require meteorology is elected only by those who expect to teach. As yet fo financial reasons this and all the subjects in the geological departme must be handled inadequately. An increased appropriation for th geological department, which is greatly needed, would make it possibl to place this and other courses in charge of specially qualified instructors. This would undoubtedly enhance its importance and increase the demand for it.

As already stated, I think the subject has much inherent educational value, though as yet not fully available. This will be remedied as the science develops and when greater importance is attached to it by placing it in charge of specially qualified and interested instructors.

There are undoubtedly many ways in which the services of a trained meteorologist could be made available in business enterprises, and the time is coming when this will be done. At the present time, however, I think one of the most important steps to be made is the general extension of knowledge of the elementary facts and principles of climatic control. Much of the invaluable work of the Weather Bureau now goes for naught through lack of knowledge on the part of the people of how to utilize it. The extension of the work under qualified and interested teachers in schools and colleges will help in this direction, and with better knowledge and interest among the people new ways of utilizing the services of specialists will appear.

G. N. **Salisbury**, United States Weather Bureau, Seattle, Wash.:

The high school of this city and the normal schools of the State deal ightly with meteorology as a branch of physical geography. They re supplied by this office with maps and charts, and classes occasionlly visit the office.

W. N. **Allen**, assistant principal Tacoma High School, Tacoma, Wash.:

Our course of study provides that the first half of the ninth year, ve periods of forty-five minutes each per week, be devoted to the udy of elementary meteorology and its practical application to the eather conditions of this locality in particular.

The average number of pupils enrolled in this department for the ast five years has been about 250, and the average age of the pupil bout 15 years. It will be understood, however, that while this study placed in the first year of the high school course, it is often elected y pupils of the tenth, eleventh, and twelfth years. Perhaps 450 or ore from those grades have taken the work during the last five years.

The demand for this science far exceeds the demand for any one of e other sciences taught here. This year the demand has been greater an our present facilities can accommodate.

With regard to our location and facilities, I think we are indeed rtunate. The Weather Bureau station is within a few blocks of us nd connected by telephone, while its storm signals may be seen from ur class rooms.

Commencement Bay and the low extended mud flats afford an unobtructed view, while the smoke rising from the mills indicates quite ccurately the movements of the atmosphere, and the slightest condenation or precipitation of moisture is clearly discernible about the he mountains in the distance.

In the way of apparatus we have a thermograph, a barograph, and psychrometer, in addition to numerous physical and meteorological harts. We are indebted to the Weather Bureau for copies of the ocal and national daily weather maps which are of constant and daily se to us.

Our work is based largely upon Waldo's Meteorology. We omit here it is too difficult and supplement where we think it advisable, lways substituting, wherever possible, local illustrations for those iven in the book.

Each pupil keeps a notebook wherein he records observations, experments, and general statements, with numerous examples, drawings, tc. After the first month or six weeks the pupils become very much nterested in the subject, especially as it concerns their daily life. Those who have taken the work will not think of going on an excurion without first examining the instruments and weather map, and the nfluence of this practice is very great upon their associates and home people.

D. B. **Purinton**, president, West Virginia University, Morgantown, W. Va.:

One term's work in meteorology is provided for in this university. The prerequisites are physical geography and physics. The course is n elementary one and the demand is small. The didactic value of meteorology is high, but it is adapted to small classes only. The ecuniary value of meteorology as a professional career is small.

P. W. Jenkins, director, Underwood Observatory, Lawrence University, Appleton, Wis.:

Lawrence University is located at Appleton, Wis., about 100 miles from the Milwaukee and 80 miles from the Greenbay station. The university is supported by the income from endowment and tuition. No particular fund is set apart for the study of meteorology. The course is taught by P. W. Jenkins, director of the astronomical observatory, as one of the courses of the department. Regular observations are taken twice a day, and reductions are made by the members of the class. Records are kept of the maximum, minimum, mean, set maximum, wet-bulb and dry-bulb thermometer readings, barometer, attached thermometer, wind direction, and velocity (estimated), state of the sky, precipitation, and miscellaneous phenomena. Reductions are made for the range, daily change, dew point, relative humidity, reduced barometer, and some other minor features. Reports are made as a volunteer observatory to the United States Weather Bureau.

The course consists of two recitations or lectures per week for one year, theses, and instruction in the care of instruments. The instruction is quite thorough and the course excites considerable interest on the part of the student. The members of the class are mostly sophomores who have taken physics, chemistry, and physiography. The course is elective to all students properly prepared and is credited for any teacher's degree. Most of the members of the class expect to follow some branch of engineering or enter the Government service. The text used is Waldo's Elements, while reference is made to Davis, Ward, and other authors, as well as to reports and pamphlets of the United States Weather Bureau. The text-book is not as good as it should be. It is well arranged, but not well written. A good selection of works should be placed before the student, and there seems a dearth of such books.

When such courses are organized there is at once a considerable number enrolled—with us fully as many as are enrolled in other elective courses. The class consists of from six to eight. The subject is not considered as of minor importance in the department, and the instructor is deeply interested in its development. The principal drawback is the lack of instruments.

The subject of meteorology has excellent didactic value. It is experimental, scientific, affords good mental drill, and ranks with chemistry, physics, astronomy, and geology as a didactic subject. Some students take the course for that purpose, but the greater number because it is very practical to men in all walks of life.

I believe that college men should be drawn into the Weather Bureau, and that such men should have the advantage of a course in meteorology where it is associated and taught together with correlated subjects. In this sense it should be a professional course.

I believe the Government Bureau should encourage such courses by providing literature and occasional lectures, if not regular instructors. As many of the instruments are not used in any other line of work, the Government should loan such pieces as are necessary to fit up the department similar to a Government station. In return for this the university should furnish regular records and reports of the progress of the work. The War Department makes such arrangement for military instruction.

FOURTH SESSION.

The convention was called to order at 9 o'clock a. m., September
with Professor Garriott in the chair, and proceeded with the
ding of the next paper on the programme:

PHENOLOGICAL OBSERVATIONS AT WAUSEON, OHIO.

By Mr. J. Warren Smith, *Columbus, Ohio.*

Ir. Thomas Mikesell began meteorological observations at Wau-
n, Ohio, in the late fall of 1869, and since that time he has not only
t a very complete and reliable record of the weather, but of farm
rations, the advance of vegetation, the flight of birds, and the
; blossoming of small plants, field crops, and orchard trees.

he records of Dame Nature have been opened to few men as they
e to Mr. Mikesell. He is splendidly educated, a close and keen
rver, and above all he has had the patience and has taken the
e to keep a careful and complete record of the things that his eyes
e seen and his ears have heard while about his daily work on the
n.

he scope of his observations and records has been remarkable.
example, he has given for the dozen or more different orchard
its and the different varieties of these fruits the dates when they
e in bud, first fully formed leaf, in full leaf, in blossom, fruit ripe,
plete change of foliage, divested of leaves, and whether the seeds
e plentiful or scant. For the field and garden crops he has the
iety, the dates planted, above ground, in blossom, ready for use,
, condition and quality of crop. For over 60 different birds
has the dates when first seen, number seen, date next seen, date
me common, date when last seen. He has the date of blossoming
common and botanical name of over 40 plants. For nearly 80
st trees and shrubs he has the same data as for the orchard
ts, etc.

he accompanying meteorological and phenological data were pre-
ed for the writer by Mr. Mikesell. The data as to crop yields in
ton County were obtained from the published reports of the sec-
ry of state of Ohio. His information was compiled from the
rts of the township assessors.

LOCATION OF STATION.

auseon is in central Fulton County, in northwestern Ohio, in
th latitude 41° 37′ and west longitude 84° 7′. It is in the extinct-
district of northwestern Ohio. The country is nearly level, with
ight slope toward the southeast.

he residence of Mr. Mikesell, the observer, previous to March 1,
, was about 1 mile north of town, at an elevation of 800 feet above
level and 225 feet above Lake Erie. The location was at the
h edge of the second beach of the ancient lake. The highest
ations in the vicinity are not more than 50 feet above the general
l. On March 1, 1902, Mr. Mikesell moved into Wauseon and
ted his station at 780 feet above sea level.

The soil is variable. There are ridges of yellow sand, clay ridges, and level stretches of white clay, black clay loam with blue clay subsoil, and sandy loam with clay below, a few gravel ridges, and a little red clay in patches. All these varieties of soil are often found within a radius of 30 rods.

The country when first settled was covered with a heavy growth of timber, with smaller shrubs and wild fruits. Nearly all the cultivated fruits of this latitude are raised there, but Mr. Mikesell states that some of them do not do as well as they did before the timber was cleared away so much. Peach trees used to live and bear well for fifteen or twenty years, but now seven years is about the limit. Vegetables and grains in general of the whole Temperate Zone are cultivated here, and nearly all do well.

Standard meteorological instruments have been in use and they have been well exposed.

EXPLANATION OF TABLES.

Table 1.—Mean monthly and annual temperatures from 1870 to 1903, inclusive, with normals. Before November 1, 1882, the temperature observations were taken at 5 a. m. (in summer; in winter at 6 a. m.), 1 p. m., and 9 p. m., local time; from that date until December 1, 1883, at 7 a. m., 2 p. m., and 9 p. m., local time, and since the last-named date at 7 a. m., 2 p. m., and 9 p. m., Central Standard time. Up to November 1, 1882, the mean temperature was calculated by taking one-third of the sum of the three observations; since that date, by taking one-fourth of the sum of the 7 a. m., 2 p. m., and twice the 9 p. m. observations.

The warmest month is July, with a mean of 72.8°; the coldest is January, which has an average of 23.3°. The warmest year was 1878, with a mean of 50.3°; the coldest year was 1875, with a mean of 44.2°. The normal annual temperature is 48.1°. The highest monthly mean temperature was 77.4°, in July, 1901; the lowest was 11.3°, in February, 1875.

Table 2.—This gives the mean temperature for the winter, spring, summer, and fall months, and also for the crop season, April 1 to September 30, for each year.

The coldest winter was that of 1874–75, with a mean temperature of 17.2°. The mildest winter was that of 1889–90, with a mean of 34.9°. The coolest summer (June 1 to August 31) was in 1903, with a mean of 67.1°; the warmest was in 1901, with 73.2°. The lowest mean temperature during the crop season (April 1 to September 30) was 59.5°, in 1883; the highest was 66°, in 1895.

Table 3.—Monthly and annual maximum temperatures. Previous to November 1, 1882, the highest and lowest temperatures were obtained from frequent eye observations. Since that date the extremes have been from self-registering thermometers. The highest temperature recorded was 104°, on July 7, 1874.

Table 4.—Monthly and annual minimum temperatures. The lowest temperature recorded during the thirty-four years was —32°, on December 19, 1884. The only calendar year that the temperature did not fall below zero was 1890, the lowest being zero, on March 6.

Table 5.—Highest and lowest temperatures ever recorded for each month, with dates, greatest and least monthly range, greatest and east mean daily range, mean monthly range, and mean daily range. March furnishes both the greatest and the least monthly range in emperatures.

Table 6.—Number of days each year with the temperature above 0° and below 32°. In the summer of 1874 the temperature was above 0° on 56 days. It was above 90° only 4 days in 1882 and in 1883. In 875 the minimum was below freezing on 167 days. It was below reezing only 104 days in 1878.

Table 7.—Number of days during each winter with the temperaure below zero. The average is 12. The greatest number was 42, n the winter of 1884–85, and the least, none, in the winter of 1881–82.

Table 8.—Monthly and annual precipitation, with normals. The ainfall record began in March, 1871, but was incomplete for 1873 nd the first four months of 1874. The normal annual rainfall is 7.97 inches. The greatest annual amount was 52.55 inches, in 1892; he least 28.49 inches in 1888. The least rainfall in any month was .12 inch, in February, 1877. The greatest was 11.40 inches, in May, .892. The month with the least average precipitation is January, which has a normal of 2.35 inches. May has the greatest average, .38. July has the greatest variations.

Table 9.—Number of days each year with hail, snow, and thunderstorms. A comparison of this table with the preceding temperature tables does not show any correlation between the number of thunderstorms and the temperature. For example, the years 1882 and 1883 were both very cool, but there were 12 thunderstorms in 1882 and 53 in 1883. There seems little relation also between the temperature and the number of hailstorms.

Table 10.—Number of days clear, partly cloudy, cloudy, and with 0.01 inch or more of precipitation during each month, from 1870 to 1903, together with the total for each year and the normals. The greatest number of clear days is in August; the greatest number of partly cloudy in July; the greatest number of cloudy days in December; the greatest number of rainy days in December and January.

Table 11.—Dates of first and last frosts and freezing weather, of first and last snow, number of days between last hard frost and first hard frost, last freeze to first freeze, and first freeze to last freeze, annual range of temperature, dates wheat and oat harvests began, maple and oak leaves changed color, and on which corn was ripe. The earliest date in the spring on which the last killing frost occurred was April 10, in 1899. The latest date, June 1, 1883. The average date is May 12. The earliest date that a killing frost has occurred in the fall was September 2, 1885. The latest date, October 18, 1903; the average date, September 25. In 1874 a light frost occurred on July 22, and in 1896 there was no light frost after April 22. In 1886 a light frost occurred on August 3, while in 1900 there was no light frost until October 9.

The greatest number of days between the last hard frost in the spring and the first in the fall was 171, in 1870. The least was 100, in 1883. The mean date between the last freeze in the spring and the first in the fall is July 19. The longest period between the last and first freezes was 189 days, in 1880; the shortest was 114 days, in The average number of days between the last freeze in the sprin the first in the fall is 150, while the average number of days be the last in the fall and the first in the spring is 216; the lo interval was 262 days in 1883–84, and the shortest, 165 in 1898–9

The average date for harvesting wheat is July 6; the earliest June 23, 1896; the latest, July 19, 1875. The average date for vesting oats, July 26; the earliest date, July 13, 1896; latest, A 14, 1883. The average date for the ripening of corn is Septe 19; earliest date, August 25, 1894 and 1896; latest date, Octob 1883.

Snow fell as late as May 22, in 1883, but not after March 2 1890. Snow fell on October 13, in 1872, but not until Novembe in 1878.

The average of the mean daily temperatures continues to fall January 10, when the minimum is reached. It then rises slowly is followed by a secondary depression, nearly as low as the firs January 24 to 26.

Table 12.—Dates of blossoming of apples, peaches, pears, pl and cherries from 1877 to 1904. The earliest date for all five o above came in 1878. The latest date was in 1885, following on the coldest winters on record. Peaches were entirely killed that in the vicinity of Wauseon. In 1890 peaches ripened very e pears, plums, and cherries at about the average date, while ap were considerably later than usual.

It is an interesting fact that the different varieties of apples som within a day or two of each other. The same is true of other fruits.

The average date of blossoming of apples is May 7; peaches, A 28; pears, May 3; plums and cherries, May 1.

Table 13.—Yields of crops in Fulton County from 1874 to inclusive. The yield of wheat corn, oats, barley, rye, potatoes, fruit is given in bushels per acre. The yield of clover, and hay o than clover, in tons per acre. Previous to 1899 the acreage de to the fruit crops was all included under the head "acreage de to orchards;" hence it was necessary to combine the yield of ap peaches, pears, cherries, and plums under the one head "fruit this table.

The average yield of wheat per acre is 15.6 bushels; the gre yield was 21, in 1891; least, 3.1, in 1899. Corn, average yield, largest, 53.2, in 1875; least, 13, 1883. Oats, average, 34; gre 45.9, 1899; least, 20.6, 1898. Barley, average, 23.8; greatest, 1894; least, 12.1, 1877. Rye, average, 12.6; greatest, 16.6, 1888; 2.9, 1900. Potatoes, average, 92; greatest, 134, in 1900; least, 1876. Fruit, average, 34; greatest, 77, in 1886; least, 3, in Hay, average, 1.26 tons; greatest, 1.43, in 1892; least, 0.84, in Clover, average, 1.19 tons; greatest, 1.62, in 1902; least, 0.90, in

One of the most interesting things about this table is that seems little or no relation between the years of good or poor yiel the different crops. Occasionally there is a strong contrast, as example, oats and wheat in 1898 and 1899. In 1898 wheat was but oats the poorest on record, while in the following year wheat the poorest and oats the best in the thirty years.

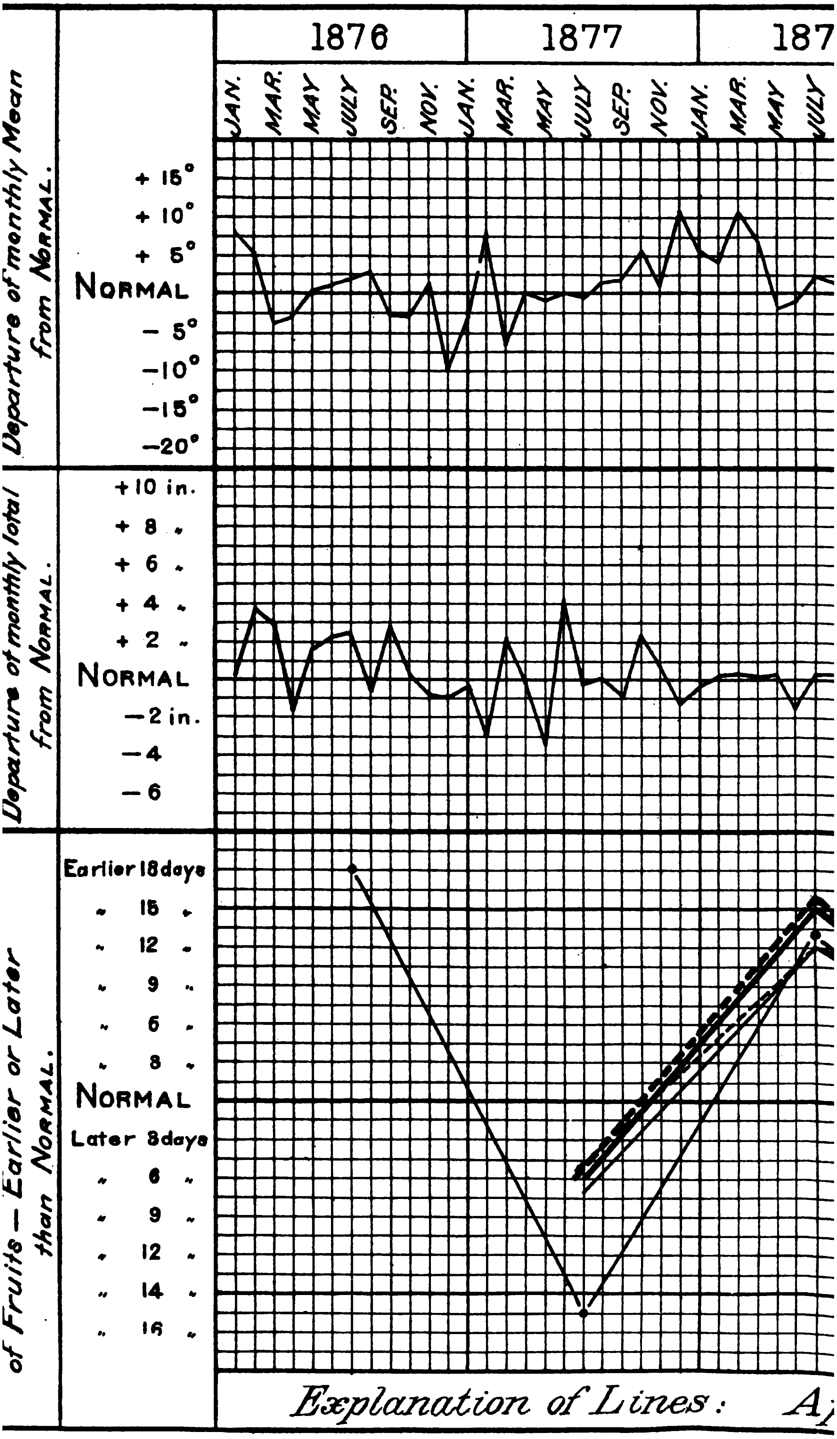

1876
1877
187
JAN.
MAR.
MAY
JULY
SEP.
NOV.
JAN.
MAR.
MAY
JULY
SEP.
NOV.
JAN.
MAR.
MAY
JULY
Departure of monthly Mean from NORMAL.
+ 15°
+ 10°
+ 5°
NORMAL
− 5°
−10°
−15°
−20°
Departure of monthly total from NORMAL.
+10 in.
+ 8 „
+ 6 „
+ 4 „
+ 2 „
NORMAL
−2 in.
−4
− 6
of Fruits — Earlier or Later than NORMAL.
Earlier 18 days
„ 15 „
„ 12 „
„ 9 „
„ 6 „
„ 3 „
NORMAL
Later 3 days
„ 6 „
„ 9 „
„ 12 „
„ 14 „
„ 16 „
Explanation of Lines: A

Table 14.—Number of acres in orchards and total yield of apples, peaches, pears, cherries, and plums, in bushels. The acreage of the different fruits previous to 1899 is not at hand; hence the yield per acre can not be determined, but it is of decided interest to know the years that were unusually good or unusually poor for the different fruits. The variation in yield is very great. Usually the year that is favorable to one fruit is favorable to all, but there are a few marked exceptions, as in 1898, when apples were very poor but other fruits were good.

In all this discussion we must not lose sight of the unpleasant possibility of errors in the figures relating to crop yields. The temperature and rainfall figures, and in fact all the data furnished by or through Mr. Mikesell have been so carefully checked that we feel that the information is as free from error as it is possible to make it. But in securing the yield data from the tables in the secretary of state's publications we found figures that were so apparently in error that they could not be used at all. In fact we were obliged to discard the data as to yield of grapes altogether, because of the considerable number of undoubted errors in the acreage figures. Therefore, while every effort has been made to secure accurate information, abnormally large or small yields in crops may be incorrect.

EXPLANATION OF DIAGRAMS.

Figure 1.—This figure shows the departure from the normal temperature and the departure from the normal precipitation by months from January, 1876, to May, 1904, and the departure from the normal dates of blossoming of apples, peaches, pears, and cherries from 1877 to 1904.

The straight heavy line represents the normal in each instance. The irregular full line at the top of the chart shows the departure from the normal temperature for each month, the extent of departure corresponding to the degrees at the left. If the month is warmer than the normal the line is above the normal line; if colder it is below.

In the irregular broken line next below, the departure from the normal precipitation is shown by months. If the month is wetter than the normal the line is shown above the normal line; if drier, below. It is comparatively easy by this figure to tell whether a winter or summer or a month or a year has been warm or cold or wet or dry. These curves show conclusively that there has been no noticeable change in the seasons and the character of the weather during the past thirty years at that point.

The temperature data are obtained from Table 1 and the precipitation data from Table 8.

The curves at the bottom of the figure show the departure from the normal date of blossoming. If earlier than the normal the curve is above the normal horizontal line. The number of days earlier is shown at the left of the figure. If the date of blossoming is later than the normal the date lines run a corresponding number of days below the normal line. The point of intersection of lines connecting the date of one year with that of the next is made on the month of July for convenience. As a matter of fact, no dates are shown on this figure; merely whether the date of blossoming is earlier or later than the normal. Table 12 gives the data from which these curves were made.

Figure 2.—This shows the yield of wheat in bushels per acre in Fulton County from 1874 to 1903, inclusive. The horizontal full line is the normal, while the yield for any year may be ascertained by running the eye from the point of intersection of the irregular line with the perpendicular year line to the figures at the left of the sheet.

This shows quickly that the yield in 1899 was the smallest during the period, slightly over 3 bushels per acre, and that the year 1891 gave the highest yield, with 21 bushels per acre.

The data for figures 2 to 9 are found in Table 13.

Figure 3.—Yield of corn, in bushels per acre, in Fulton County.

Figure 4.—Yield of oats, in bushels per acre.

Figure 5.—Yield of barley, in bushels per acre.

Figure 6.—Yield of rye, in bushels per acre.

Figure 7.—Yield of potatoes, in bushels per acre.

Figure 8.—Yield of fruit, in bushels per acre.

Figure 9.—The full line shows the yield of hay (other than clover) in tons per acre, and the broken line the yield of clover in tons per acre. The yield for each year may be determined by the figures at the left. The full horizontal line is the normal hay yield and the horizontal broken line the normal for clover.

Figure 10.—Shows the dates of blossoming of apples (full line) and of pears (broken line). The normals are shown by the full horizontal line and broken horizontal line, respectively. The data for this figure and also for figure 2 are found in Table 12. The dates were not recorded in 1882.

Figure 11.—This shows the dates of blossoming of peaches, plums, and cherries, together with the normal date lines. The normal date for plums and cherries is the same, hence there are only two normal date lines. There were so many dates missing for plums previous to 1884 that the curve began with that year. There were no peach blossoms in 1885 and 1897.

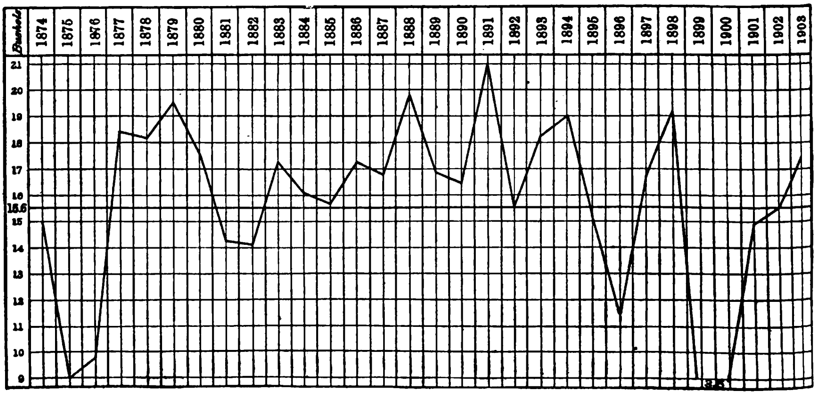


FIG. 2.—Yield of wheat in bushels per acre.

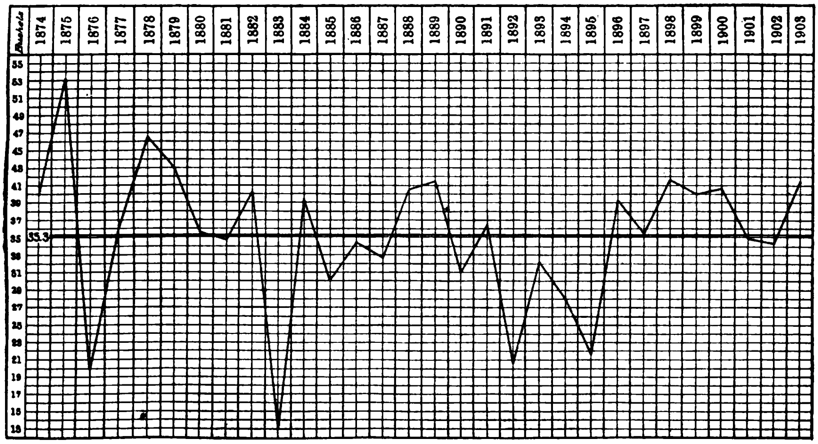


FIG. 3.—Yield of corn in bushels per acre.

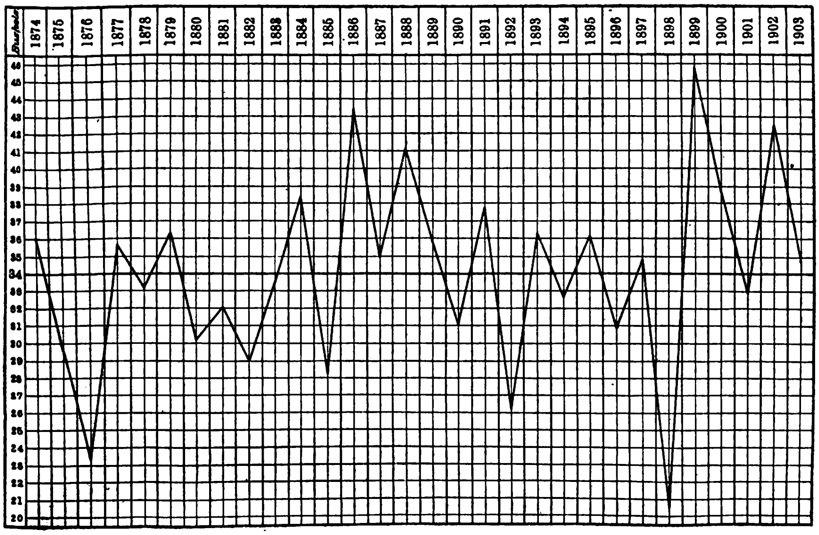


FIG. 4.—Yield of oats in bushels per acre.

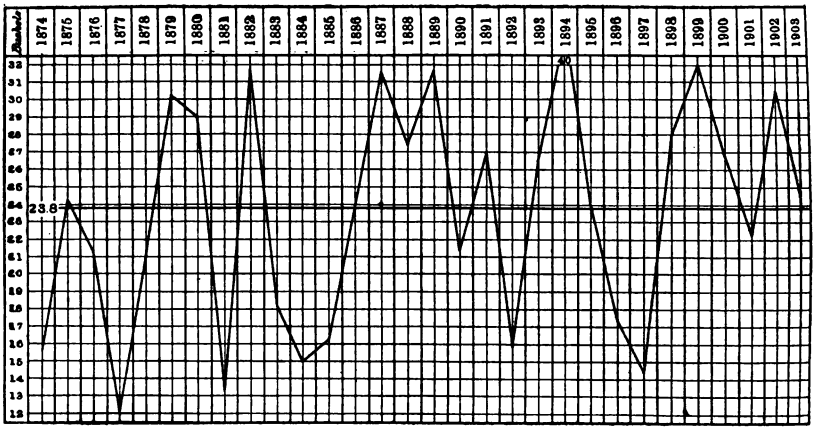


FIG. 5.—Yield of barley in bushels per acre.

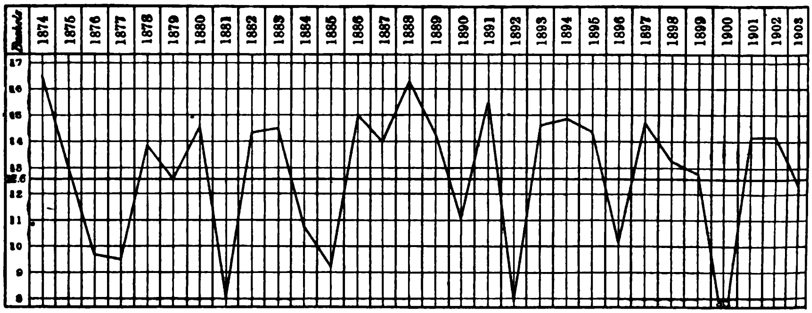


FIG. 6.—Yield of rye in bushels per acre.

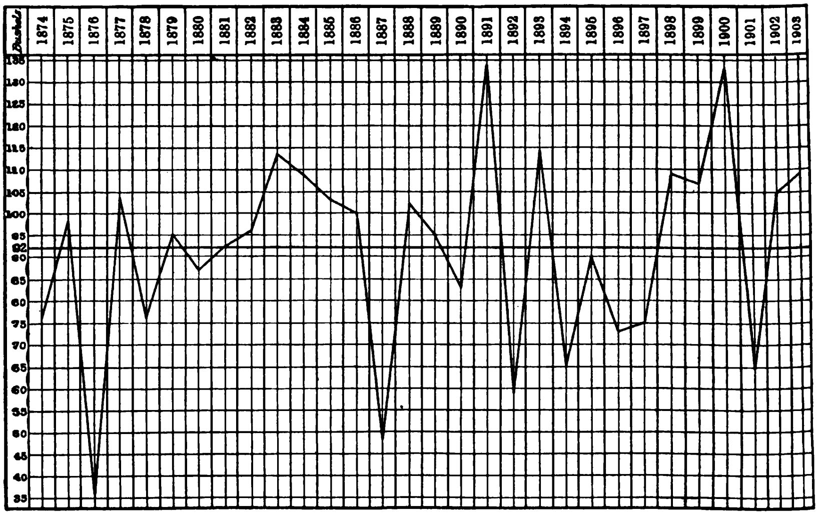


FIG. 7.—Yield of potatoes in bushels per acre.

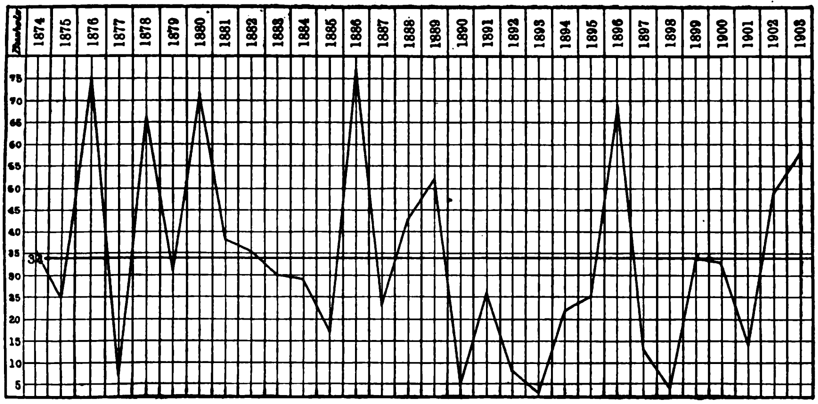


FIG. 8.—Yield of fruit in bushels per acre.

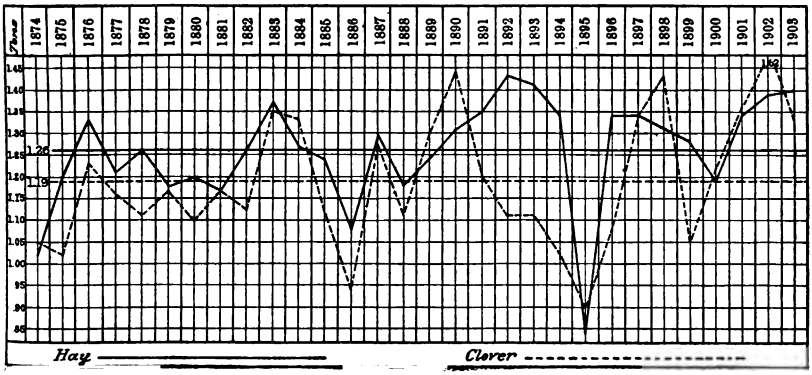


FIG. 9.—Yield of hay and clover in tons per acre.

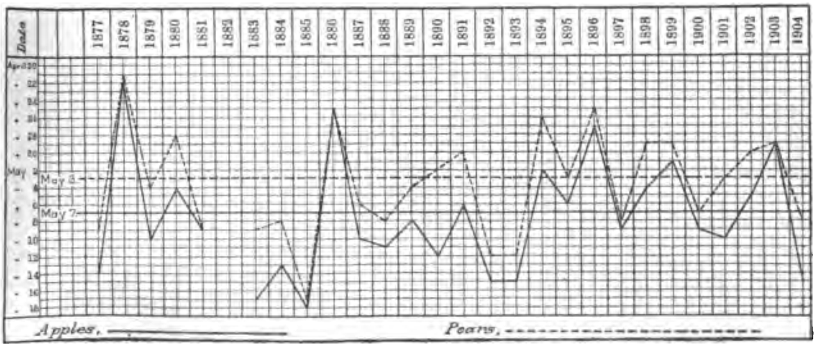


FIG. 10.—Dates of blossoming of apples and pears.

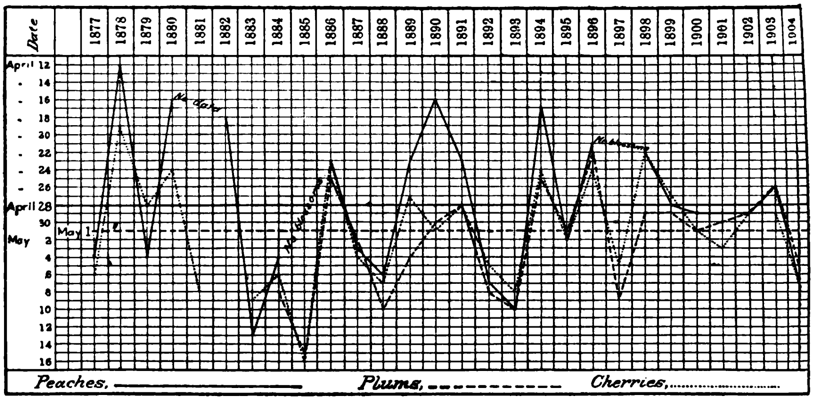


FIG. 11.—Dates of blossoming of peaches, plums, and cherries.

DISCUSSION OF DATA.

We shall not attempt to follow out all the interesting lines of discussion that are possible with the data before us, neither shall we exhaust any particular line; but make suggestions here and there, then leave the data for more complete study along special lines by those interested in special subjects.

Figure 2.—The yield of wheat was considerably above the average in 1879, 1888, 1891, 1894, and 1898, and below the normal in 1875, 1876, 1896, 1899, and 1900.

A careful inspection of figure 1 shows that the reasons for the good and poor wheat yields can not be explained by the monthly departures from the normal of temperature or of rainfall, although the low yield of 1875 was preceded by the coldest winter on record, that of 1896 was preceded by a very cold January, that of 1899 by a cold February, and that of 1900 by a cold February and March. On the other hand the good yield of 1879 was preceded by a cold December, that of 1888 by a cold winter. A mild winter preceded the good yields of 1891, 1894, and 1898.

It is apparent that the wheat yield is affected materially by alternate freezing and thawing, short periods of severe cold, snow covering, and to some extent weather favorable for growth in the fall, as well as by the attacks of the fly and short periods of favorable or unfavorable weather in the spring. The February (1899) preceding the lowest yield of the period gave the coldest week ever experienced in many sections of the State, with very little snow protection in Fulton County. January and February, 1900, also gave short cold periods, with little snow protection.

Figure 3.—Corn. The relation between the rainfall in July and the yield of corn is not so universally well marked in a small district as in a large one, yet very nearly every year with a large corn yield has a July precipitation above the normal, and nearly every year with a small corn yield has a deficient July rainfall.

One exception is the year 1875, with a very large corn yield in Fulton County, but the rainfall for June was much above normal.

Another was in 1883, when the yield was the lowest on record, although the July rainfall was above normal. This, however, was a cold, wet summer, when the number of days between spring and fall frosts was the least on record. A killing frost was recorded on June 1 and a light frost on June 14.

Figure 4.—Oats. By comparing the years of best yields of oats and the years of poorest yields with figure 1, it is apparent that June or July, or both, should be moderately cool and dry to produce the best results. The best years are 1884, 1886, 1888, 1899, and 1902, all with cool, dry summers. The poorest years were 1876, 1885, 1892, and 1898, all with warm, wet summers.

Figure 5.—Barley. Spring barley was considered in this discussion, and although the acreage of this crop is small it is apparent that it does best in warm and dry weather and poorest when it is cool and wet.

Figure 6.—Rye. Unfavorable winter weather affects this crop as it does wheat; hence the years with poorest yields have been preceded generally by a cold, unfavorable March, or else the whole winter has been cold. The years with best yields have been preceded by com-poor yields accompany warm and dry springs.

Figure 7.—Potatoes. The best potato years have been those with the average summer temperature about or below normal and with sufficient precipitation in June and July, while the poor years have generally had a high summer temperature. The September rainfall has been below the normal in the best years.

Figure 8.—Fruit. Even a casual inspection shows that poor fruit years have been preceded by cold winter conditions and good years by comparatively mild winter conditions. Although the acreage of the different fruits is not given, a study of Table 14 in connection with figure 1 is interesting. A comparison of the dates of the last killing frost in the spring, in Table 11, is important in connection with the yield of peaches, as shown in Table 14.

Figure 9.—It is apparent that the yield of clover is affected by the condition of the preceding winter. The best yields of hay, other than clover, are with a good rainfall in April, May, and June, while poor yields accompany warm and dry springs.

Figures 10 and 11.—The date of blossoming of the fruits depends to a marked degree upon the temperature of March and April. It is hard to understand why peaches should have ripened so early in 1890 while the other fruits blossomed at about the normal date or later. But it is probable that the warm spell that placed the average temperature of April slightly above the normal was of sufficient length to bring out peaches, but not long enough to start the other fruits.

TABLE 1.—*Monthly and annual mean temperatures.*

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Yea
1870	27.9	27.7	32.6	50.2	62.3	70.0	74.7	70.1	66.4	53.1	39.4	25.1	
1871	25.9	27.1	40.9	50.4	60.2	68.4	70.9	72.5	58.7	53.0	32.5	21.9	
1872	21.0	22.5	27.8	49.3	59.0	70.0	74.8	72.8	64.2	49.6	30.5	17.1	
1873	16.6	22.1	30.7	44.4	58.5	72.4	72.2	71.4	61.1	47.0	31.6	30.8	
1874	31.9	27.5	34.2	38.6	60.3	71.4	73.5	70.1	64.8	50.9	28.9	28.2	
1875	12.2	11.3	29.5	41.5	57.5	67.7	71.5	66.3	59.1	46.0	33.2	34.5	
1876	32.3	31.0	29.9	44.4	59.0	70.0	74.9	72.5	60.2	46.5	38.1	17.9	
1877	20.0	33.4	26.5	47.2	57.7	68.7	72.3	71.0	64.4	55.6	37.7	38.8	
1878	28.2	29.5	43.2	54.8	56.8	67.2	75.2	71.5	64.3	50.8	39.4	22.6	
1879	21.8	24.5	35.7	47.3	59.1	67.1	74.9	69.3	57.9	59.0	38.3	29.6	
1880	37.7	31.7	31.1	47.7	64.3	67.1	70.5	70.0	64.2	51.5	27.9	20.7	
1881	16.4	21.9	30.9	41.2	63.8	65.5	73.1	72.1	71.1	54.8	39.0	34.9	
1882	25.9	35.4	37.8	44.6	52.2	66.0	67.7	70.6	62.6	52.9	37.7	24.0	
1883	18.7	23.6	28.0	45.4	52.7	66.5	70.0	65.5	57.2	48.7	40.3	28.4	
1884	14.5	26.2	33.1	44.9	58.3	69.5	70.1	68.4	67.8	53.2	35.5	24.5	
1885	15.6	11.9	24.5	45.3	56.9	66.5	74.4	65.8	60.7	46.9	38.5	28.3	
1886	19.0	25.0	34.5	50.8	60.4	67.4	73.0	69.5	63.2	52.0	34.9	19.3	
1887	19.3	28.3	31.5	46.2	63.2	69.2	77.1	68.8	61.6	46.5	37.1	26.9	
1888	17.5	24.7	29.7	46.3	55.2	69.3	71.6	69.9	59.2	46.0	40.1	31.2	
1889	29.4	20.2	37.2	47.2	58.4	64.8	71.5	68.0	61.0	45.2	38.1	38.7	
1890	33.2	32.9	30.8	48.5	56.1	72.8	72.7	67.6	58.8	50.1	40.3	27.6	
1891	27.9	30.9	30.7	49.6	56.5	69.2	68.3	69.8	67.6	49.1	35.4	35.5	
1892	19.2	29.9	31.7	45.7	56.4	70.2	72.7	70.8	62.6	49.8	34.9	25.5	
1893	13.7	22.7	35.1	46.0	56.6	70.6	73.4	69.2	62.9	50.6	36.8	27.9	
1894	30.0	23.5	41.8	49.0	56.8	72.2	74.7	69.9	65.2	50.6	34.4	32.3	
1895	18.4	17.9	30.5	50.5	60.6	72.2	72.0	73.0	67.7	44.4	36.9	29.0	
1896	25.1	26.7	30.3	55.1	66.2	68.0	71.6	70.6	60.1	46.3	40.9	29.5	
1897	21.2	27.9	36.6	46.7	55.7	66.4	74.9	67.2	65.4	55.0	38.4	27.8	
1898	27.7	27.3	41.8	46.5	59.6	70.3	74.2	71.4	65.9	51.3	35.9	25.8	
1899	24.1	20.1	31.3	52.4	61.1	71.2	72.4	72.8	59.8	55.6	41.0	27.0	
1900	27.9	22.9	27.9	48.8	62.0	67.4	72.1	75.4	67.3	58.5	38.6	28.7	
1901	25.7	15.7	34.6	47.4	57.3	70.3	77.4	72.0	63.7	51.8	35.4	24.0	
1902	24.4	20.8	33.9	46.2	59.8	64.5	72.7	66.4	59.7	51.7	46.1	26.1	
1903	23.8	25.5	42.3	47.3	62.1	63.1	70.9	67.3	62.1	50.7	34.4	20.6	
Mean	23.3	25.0	33.4	47.3	58.9	68.6	72.8	69.8	62.9	50.7	36.7	27.4	

TABLE 2.—*Seasonal mean temperatures.*

Year.	Dec. 1 to Feb. 28.	Mar. 1 to May 31.	June 1 to Aug. 31.	Sept. 1 to Nov. 30.	Apr. 1 to Sept. 30
1870	29.2	48.4	69.2	53.0	65.6
1871	26.0	50.5	70.6	48.1	63.5
1872	21.8	45.4	72.5	48.1	65.0
1873	18.6	44.5	72.0	46.6	63.3
1874	30.1	44.4	71.7	48.2	63.1
1875	17.2	42.8	68.5	46.1	60.6
1876	32.6	44.4	72.5	48.3	63.5
1877	23.8	43.8	70.7	52.6	63.5
1878	32.2	51.6	71.3	51.5	65.0
1879	22.8	47.4	70.4	51.7	62.6
1880	33.0	47.7	69.2	47.9	64.0
1881	19.7	45.3	70.2	55.0	64.5
1882	32.1	44.9	68.1	51.1	60.6
1883	22.1	42.0	67.3	48.7	59.5
1884	23.0	45.4	69.3	52.2	63.2
1885	17.3	42.2	68.9	48.7	61.6
1886	24.1	48.6	70.0	50.0	64.0
1887	22.6	47.0	71.7	48.4	64.4
1888	23.0	43.7	70.3	48.4	
1889	25.4	47.6	68.1	48.1	
1890	34.9	45.4	71.0	49.7	
1891	28.8	45.6	69.1	50.7	
1892	28.2	44.6	71.2	49.1	
1893	20.6	45.9	71.1	50.1	
1894	27.1	49.2	72.3	50.1	
1895	27.0	47.2	72.4	49.7	
1896	26.9	50.5	70.3	49.1	
1897	26.2	46.3	69.5	52.9	
1898	27.2	49.3	72.0	50.7	
1899	23.3	48.3	72.1	52.1	
1900	25.9	46.2	71.6	54.8	
1901	23.4	46.4	73.2	50.3	
1902	23.1	48.4	67.9	52.5	
1903	25.1	50.6	67.1	49.1	
Mean	25.4	46.5	70.7	50.1	

TABLE 3.—*Monthly and annual maximum temperatures.*

ar.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
....	49	45	55	84	85	96	92	89	90	76	72	56	96
....	65	61	68	80	91	90	94	98	90	80	57	55	98
....	46	60	60	87	86	93	94	94	94	82	55	40	94
....	45	55	58	83	86	95	92	95	91	84	65	58	95
....	62	50	71	74	103	99	104	102	97	81	67	52	104
....	46	54	80	88	95	96	94	92	94	79	62	70	96
....	70	61	66	76	91	94	96	96	80	76	75	43	96
....	52	57	56	78	95	90	94	92	87	86	60	61	95
....	50	55	72	84	82	97	98	92	89	83	64	40	98
....	50	45	70	85	90	97	96	94	88	87	72	57	97
....	62	63	62	80	88	92	97	92	89	80	60	50	97
....	39	47	50	83	94	90	98	101	100	80	66	56	101
....	53	58	66	82	80	92	92	88	87	83	75	45	92
....	43	60	69	84	83	89	92	93	89	85	66	56	93
....	50	58	65	79	82	92	92	94	95	88	63	56	95
....	48	51	56	82	83	90	98	91	88	78	69	54	98
....	52	57	75	84	89	95	99	95	90	84	71	56	99
....	59	56	62	84	92	92	101	100	95	83	68	58	101
....	44	52	71	86	84	98	94	98	92	76	76	56	98
....	55	52	71	79	91	85	93	94	90	80	62	64	94
....	66	64	61	78	88	96	98	100	88	82	69	50	100
....	53	56	62	81	85	94	93	100	96	88	63	59	100
....	55	55	61	77	83	91	99	95	88	81	59	59	99
....	49	48	69	82	87	95	95	95	97	85	68	66	97
....	56	58	78	85	87	97	100	98	98	81	66	58	100
....	50	61	67	85	96	100	99	99	97	76	73	58	100
....	52	64	66	89	92	92	93	97	90	78	70	59	97
....	58	46	64	81	83	93	102	95	99	94	65	57	102
....	64	62	71	80	83	94	101	95	96	89	69	54	101
....	53	62	66	91	87	98	97	97	94	89	62	60	98
....	56	64	51	83	91	91	93	99	96	92	67	58	99
....	52	37	72	86	86	98	101	97	96	82	64	63	101
....	46	54	70	85	93	93	95	92	88	80	76	50	95
....	59	49	80	82	93	92	97	96	93	83	71	41	97
m	70	64	80	91	103	100	104	102	100	94	76	70	104

TABLE 4.—*Monthly and annual minimum temperatures.*

r.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
....	−2	−10	2	28	42	48	50	41	41	32	21	−13	−13
....	−2	0	22	28	32	39	43	48	25	21	−3	−24	−24
....	−12	−14	3	13	29	46	50	42	30	27	−2	−24	−24
....	−29	−10	−12	30	34	38	46	44	30	21	4	10	−30
....	−13	−6	7	6	29	38	45	42	30	12	6	−5	−13
....	−20	−24	−13	10	30	36	45	41	29	17	5	−2	−24
....	7	0	0	24	23	48	51	42	39	21	11	−10	−10
....	−14	15	−2	25	30	40	54	52	39	32	10	18	−14
....	−4	−3	20	30	31	42	56	46	40	23	21	−9	−9
....	−21	−6	11	16	29	43	54	45	31	21	7	−3	−21
....	18	4	15	17	33	46	49	46	33	25	−8	−19	−19
....	−14	−12	13	5	33	45	51	49	40	31	10	11	−14
....	3	15	19	20	28	40	48	49	38	22	4	−16	−16
....	−18	−12	−17	18	27	34	43	41	29	26	6	−5	−18
....	−32	−8	−8	22	29	48	44	39	30	18	5	−32	−32
....	−29	−24	−7	12	21	38	46	40	31	14	16	−7	−29
....	−14	−18	5	14	32	36	46	43	36	29	17	−5	−18
....	−20	0	7	17	40	44	47	39	25	15	8	−4	−20
....	−14	−9	−6	23	23	35	43	38	30	23	20	6	−14
....	1	−13	10	19	26	38	46	45	28	17	9	15	−13
....	1	5	0	21	28	39	42	41	34	29	17	6	0
....	3	0	−4	20	28	40	41	39	37	20	1	9	−4
....	−23	3	6	20	32	52	44	47	39	21	14	−7	−23
....	−15	−9	6	23	33	44	47	40	27	18	6	−5	−15
....	−6	−7	6	23	33	35	44	40	32	23	11	−5	−7
....	−11	−16	−2	22	29	42	45	45	32	13	13	−5	−16
....	−10	−6	0	21	43	45	50	44	26	20	12	−12	−12
....	−21	1	12	16	33	38	53	41	28	81	12	−7	−21
....	7	−8	9	16	34	44	42	44	38	25	8	−5	−8
....	−13	−17	6	15	36	43	48	49	29	20	23	−5	−17
....	−4	−6	−4	21	26	40	47	53	35	25	9	2	−6
....	−10	−11	−1	22	32	37	51	47	32	24	11	−11	−11
....	−3	−10	9	22	31	41	47	44	32	27	20	−1	−10
....	−9	−6	20	19	25	45	46	45	35	22	9	−1	−9
m	−32	−24	−17	5	21	34	41	38	25	12	−8	−32	−32

TABLE 5.—*Temperatu ximum, minimum, and range.*

Month.	Maximum.			Minimum.			Monthly range.			
							Greatest.		Least.	
	Temperature.	Year.	Day.[a]	Temperature.	Year.	Day.[b]	° F.	Year.	° F.	Year.
January	69.5	1876	1	−31.7	1884	25	82.2	1884	37.4	1897
February	64.3	1896	27	−24.3	1885	13	78.5	1875	42.4	1877
March	80.0	1903	18	−17.4	1883	20	92.5	1875	36.8	1881
April	91.0	1899	29	5.2	1881	5	78.1	1881	52.0	1871 1876
May	103.2	1874	29	21.0	1885	3	74.2	1874	43.0	1870
June	99.6	1895	3	34.5	1883	1	62.4	1888	38.3	1892
July	104.5	1874	7	41.0	1891	27	59.5	1874	40.0	1877
August	102.0	1874	20	38.8	1888	23	61.8	1891	38.8	1888
September	100.3	1881	5	24.9	1887	24	71.7	1897	41.5	1876
October	94.0	1897	1	12.0	1874	14	69.7	1884	43.8	1870
November	76.5	1888	1	− 8.5	1880	19	70.1	1882	39.1	1899
December	70.0	1875	31	−32.4	1884	19	88.7	1884	42.4	1903
For 34 years	104.5	1874	7	−32.4	1884	19	92.5	[c]1875	36.8	[c]1881

Month.	Mean daily range.				Mean monthly range.	Mean daily range.
	Greatest.		Least.			
	° F.	Year.	° F.	Year.	° F.	° F.
January	24.3	1875	12.2	1871	62.0	17.1
February	26.2	1885	12.8	1897	61.7	18.4
March	24.0	1883	12.2	1881	61.9	19.0
April	28.9	1887	15.5	1873	62.9	22.9
May	28.6	1891	18.5	1882	57.7	24.0
June	30.6	1894 1895	18.4	1880 1881	52.2	24.5
July	32.3	1886	18.3	1878	49.2	25.0
August	32.3	1894	16.0	1882	51.5	25.4
September	36.3	1897	14.9	1876	59.4	25.7
October	26.8	1874	15.4	1870	60.1	22.6
November	24.0	1884	11.3	1876	56.9	17.3
December	21.3	1884	11.0	1880	56.9	15.7
For 34 years	36.3	1897	11.0	1880	57.7	21.4

[a] July. [b] December. [c] March.

TABLE 6.—*Number of days with temperature above 90° and below 32°.*

Year.	Above 90°.	Below 32°.	Year.	Above 90°.	Below 32°.	Year.	Above 90°.	Below 32°.
1870	15	131	1882	4	141	1894	47	122
1871	12	132	1883	4	157	1895	55	158
1872	23	161	1884	21	163	1896	19	147
1873	15	153	1885	13	158	1897	33	130
1874	56	154	1886	21	142	1898	25	123
1875	24	167	1887	37	156	1899	41	133
1876	23	137	1888	17	155	1900	31	136
1877	16	119	1889	11	139	1901	38	149
1878	15	104	1890	26	136	1902	18	127
1879	20	136	1891	25	135	1903	24	138
1880	13	131	1892	17	153			
1881	26	142	1893	23	148	Average	24	142

TABLE 7.—*Number of days in each winter with temperature below zero.*

Winter of—	Days.	Winter of—	Days.	Winter of—	Days.	Winter of—	Days.
1869–70	2	1878–79	11	1887–88	18	1896–97	7
1870–71	6	1879–80	2	1888–89	5	1897–98	4
1871–72	19	1880–81	27	1889–90	1	1898–99	12
1872–73	23	1881–82	0	1890–91	2	1899–1900	10
1873–74	2	1882–83	23	1891–92	9	1900–1901	15
1874–75	33	1883–84	19	1892–93	20	1901–2	14
1875–76	3	1884–85	42	1893–94	5	1902–3	7
1876–77	10	1885–86	13	1894–95	21		
1877–78	3	1886–87	22	1895–96	10	Average	12

TABLE 8.—*Monthly and annual precipitation.*

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
71	------	------	2.05	3.53	2.80	8.09	4.16	2.97	0.55	0.95	3.45	1.76	------
72	1.32	0.82	.97	1.31	3.72	1.43	7.26	4.26	3.78	1.38	1.83	2.93	31.01
73	------	------	------	------	------	------	------	------	------	------	------	------	------
74	------	------	------	------	1.70	5.47	2.59	1.44	.66	.93	2.77	.41	------
75	2.14	2.68	3.40	1.53	6.06	6.06	1.60	3.82	2.23	3.42	2.38	2.96	38.28
76	2.57	6.81	6.52	1.53	6.13	6.36	6.37	2.20	4.12	2.82	2.51	1.64	49.58
7	2.02	.12	5.61	3.07	1.14	8.21	3.79	2.74	1.56	4.88	4.02	1.40	38.56
8	2.14	3.26	3.78	3.21	4.70	2.58	4.28	4.03	1.89	2.42	2.72	2.23	37.24
9	1.29	1.50	2.88	2.51	3.06	2.82	4.20	2.72	5.29	.95	5.15	4.32	36.69
0	3.58	1.48	2.78	4.90	6.25	3.31	4.99	4.72	2.69	2.67	2.54	1.23	41.14
1	1.77	4.28	3.73	1.55	1.33	8.43	5.03	1.25	2.36	8.92	5.83	3.58	48.06
2	2.14	2.91	3.43	2.38	4.96	3.18	2.57	3.48	1.35	2.59	2.81	1.81	33.61
3	1.72	5.11	1.70	1.63	5.97	4.73	6.44	1.67	2.96	4.37	2.88	2.41	41.59
4	1.93	5.02	2.78	1.42	3.95	2.79	.4.20	1.12	1.85	8.01	1.46	3.38	32.91
5	3.22	1.15	.62	3.71	5.61	3.83	3.03	4.36	2.14	3.03	2.73	2.57	36.00
6	2.78	.84	1.56	3.19	2.69	2.01	.31	4.86	4.47	1.94	2.66	3.07	30.38
7	2.36	7.19	1.49	1.52	3.50	3.55	2.87	1.52	1.70	1.97	3.78	2.69	34.14
8	2.40	1.96	3.64	2.27	3.36	3.52	.86	1.95	.84	1.93	3.88	1.88	28.49
9	2.17	1.77	2.96	1.90	8.22	3.69	4.82	1.54	.79	.96	3.67	2.85	35.31
0	4.14	3.43	3.45	5.29	4.79	3.88	.48	3.48	2.69	3.76	2.25	1.16	38.80
1	2.56	4.58	4.44	4.39	1.49	4.21	2.36	3.43	.86	1.85	5.02	1.91	37.10
2	1.42	3.56	5.54	5.17	11.40	8.65	2.95	2.88	4.61	.39	4.38	2.10	52.55
3	2.47	5.34	3.97	6.06	2.32	3.09	5.07	.49	2.06	3.31	3.88	4.69	42.75
4	2.27	4.48	3.18	3.96	4.11	2.33	.72	.87	3.74	2.42	1.80	2.18	32.06
5	2.27	.76	1.38	2.10	2.75	.64	.71	2.82	1.18	1.19	6.30	6.72	28.82
6	2.20	2.24	2.80	6.65	3.44	4.12	10.91	4.24	4.58	1.20	2.25	1.84	46.47
7	3.76	1.35	6.66	5.69	3.90	3.33	3.67	1.88	.76	.77	5.20	1.88	38.85
8	4.28	2.75	8.08	2.03	3.76	3.57	4.91	2.24	3.22	3.42	3.39	3.28	44.93
9	3.90	4.52	5.47	1.19	4.53	1.11	4.52	.84	2.70	2.50	2.17	3.36	36.81
0	1.50	5.75	2.17	4.04	4.12	3.01	5.71	2.97	1.61	3.09	4.48	.93	39.38
1	2.10	1.38	3.57	2.99	3.67	5.15	2.36	1.93	1.95	2.88	1.61	5.73	35.32
2	.71	1.18	4.96	1.30	6.45	7.73	6.24	.86	7.93	2.07	2.37	3.05	44.85
3	1.24	4.76	2.51	5.41	2.40	2.77	5.91	4.84	2.48	2.50	1.84	2.27	38.93
Mean	2.35	3.10	3.49	3.14	4.38	4.02	3.93	2.62	2.55	2.51	3.25	2.63	37.97

TABLE 9.—*Number of days each year with hail, snow, and thunderstorms.*

Year.	Hail.	Snow.	Thunder-storms.	Year.	Hail.	Snow.	Thunder-storms.
70	1	27	19	1888	2	39	36
71	0	50	14	1889	2	33	36
72	2	69	5	1890	5	35	43
73	0	24	27	1891	8	36	44
74	1	26	25	1892	6	46	61
75	3	43	29	1893	5	57	46
76	2	55	45	1894	12	31	61
77	2	39	26	1895	4	48	31
78	0	42	29	1896	7	36	59
79	0	52	22	1897	6	48	41
80	1	33	22	1898	3	37	40
81	0	56	18	1899	6	37	39
82	0	29	12	1900	1	56	42
83	3	47	53	1901	3	44	42
84	2	49	44	1902	12	36	45
85	5	57	49	1903	3	43	46
86	2	51	48				
87	5	49	47	Average	3	43	37

TABLE 10.—*Number of days clear, partly cloudy, cloudy, and with 0.01 inch o more of precipitation.*

Year.	January.				February.				March.				April.				May.		
	Clear.	Partly cloudy.	Cloudy.	Rain.	Clear.	Partly cloudy.	Cloudy.	Rain.	Clear.	Partly cloudy.	Cloudy.	Rain.	Clear.	Partly cloudy.	Cloudy.	Rain.	Clear.	Partly cloudy.	Cloudy.
1870	9	4	20	19	12	5	11	8	10	6	15	12	13	8	9	10	16	12	3
1871	1	8	22	18	8	12	13	15	6	10	15	14	9	12	9	13	19	4	8
1872	5	6	20	11	9	8	12	8	11	9	11	10	14	6	10	11	11	11	9
1873	6	3	22	10	5	10	13	12	5	9	17	11	6	7	17	15	8	13	10
1874	1	8	22	20	7	4	17	17	9	10	12	14	8	9	13	14	14	10	7
1875	6	10	15	16	8	7	13	15	4	16	11	17	7	15	8	13	6	20	5
1876	4	12	15	16	6	9	14	13	1	13	17	19	11	8	11	13	9	11	11
1877	8	10	13	15	12	9	7	2	7	10	14	21	11	10	9	12	14	8	9
1878	4	7	20	17	7	3	18	14	5	6	20	18	5	8	17	16	6	11	14
1879	8	2	21	12	3	5	20	15	2	8	21	14	12	1	17	13	13	7	11
1880	7	3	21	14	6	10	13	13	7	8	16	9	8	3	19	14	17	2	12
1881	5	4	22	16	3	8	17	19	3	9	19	16	4	8	18	12	14	9	8
1882	3	4	24	15	8	5	15	12	3	8	20	17	6	10	14	8	6	11	14
1883	7	9	15	18	6	8	14	15	7	12	12	14	8	14	8	13	7	13	11
1884	5	8	18	11	2	7	20	17	4	9	18	16	7	7	16	10	12	9	10
1885	7	15	9	16	9	7	12	19	6	13	12	12	7	13	10	14	5	11	15
1886	4	7	20	20	5	9	14	11	5	12	14	15	8	13	9	11	11	15	5
1887	4	9	18	18	2	8	18	21	7	15	9	10	8	16	6	13	12	12	7
1888	5	6	20	18	6	11	12	11	7	10	14	15	14	9	7	9	5	17	9
1889	6	8	17	13	2	13	13	14	10	13	8	6	6	13	11	14	8	12	11
1890	6	7	18	21	6	5	17	16	4	16	11	17	10	11	9	11	6	15	10
1891	1	11	19	13	1	12	15	17	2	12	17	19	7	13	10	13	12	12	7
1892	8	10	13	14	2	6	21	16	5	14	12	14	4	13	13	11	2	12	17
1893	2	12	17	22	4	9	15	18	5	11	15	14	2	10	18	20	5	11	15
1894	5	13	13	10	6	12	10	15	8	14	9	13	9	7	14	17	6	16	9
1895	3	14	14	16	9	7	12	11	8	17	6	12	11	8	11	9	16	8	7
1896	3	10	18	11	4	12	12	13	7	11	13	13	12	10	8	12	12	10	9
1897	2	10	19	17	3	5	20	8	8	9	14	19	4	13	13	16	13	11	7
1898	2	11	18	15	1	10	17	15	10	4	17	14	11	8	11	10	11	12	8
1899	7	13	11	16	6	12	10	12	1	8	22	17	7	16	7	6	8	12	11
1900	5	10	16	15	5	10	13	14	7	12	12	15	14	8	8	12	9	11	11
1901	5	5	21	16	5	13	10	10	6	5	20	18	9	4	17	13	6	13	12
1902	8	12	11	11	8	8	12	10	5	15	11	14	5	15	10	7	7	19	5
1903	8	10	15	14	7	6	15	14	5	12	14	11	12	7	11	14	11	14	6
Average for 34 years	5	9	17	15	6	8	14	14	6	11	14	14	8	10	12	12	10	12	9

Year.	June.				July.				August.				September.		
	Clear.	Partly cloudy.	Cloudy.	Rain.	Clear.	Partly cloudy.	Cloudy.	Rain.	Clear.	Partly cloudy.	Cloudy.	Rain.	Clear.	Partly cloudy.	Cloudy.
1870	12	15	3	15	14	14	3	17	15	14	2	8	9	18	3
1871	15	8	7	11	13	9	9	8	11	8	12	11	15	3	12
1872	12	14	4	9	11	11	9	12	15	10	6	13	14	9	7
1873	13	12	5	8	8	14	9	14	11	14	6	7	16	5	9
1874	10	10	10	12	9	10	12	11	15	11	5	9	16	6	8
1875	5	14	11	19	2	21	8	14	8	17	6	13	7	14	9
1876	7	11	12	16	9	17	5	17	11	15	5	9	4	12	14
1877	4	12	14	16	16	7	8	15	13	8	10	9	18	3	9
1878	10	8	12	6	9	11	11	12	12	10	9	8	16	2	12
1879	14	3	13	12	14	10	7	8	13	5	13	10	9	7	14
1880	8	8	14	12	10	9	12	14	10	7	14	14	9	8	13
1881	5	12	13	13	17	6	8	7	19	4	8	7	10	7	13
1882	4	12	14	14	14	8	9	11	4	10	17	16	12	8	10
1883	7	12	11	16	9	15	7	10	10	16	5	6	7	16	7
1884	9	15	6	13	8	15	8	12	16	11	4	8	14	12	4
1885	12	14	4	10	11	16	4	10	10	13	8	14	12	11	7
1886	12	14	4	12	14	12	5	6	9	16	6	12	8	18	4
1887	9	15	6	13	18	12	1	6	10	13	8	8	9	8	13
1888	11	10	9	14	11	16	4	12	11	15	5	10	14	13	3

10.—*Number of days clear, partly cloudy, cloudy, and with 0.01 inch or more of precipitation*—Continued.

Year,	June.				July.				August.				September.			
	Clear.	Partly cloudy.	Cloudy.	Rain.	Clear.	Partly cloudy.	Cloudy.	Rain.	Clear.	Partly cloudy.	Cloudy.	Rain.	Clear.	Partly cloudy.	Cloudy.	Rain.
	5	15	10	16	14	13	4	10	21	4	6	8	13	9	8	7
	10	13	7	9	15	14	2	7	13	12	6	7	10	13	7	13
	7	16	7	17	11	17	3	10	9	16	6	11	17	11	2	5
	6	11	13	21	12	16	3	8	12	12	7	10	13	9	8	11
	11	13	6	10	11	16	4	12	15	6	4	5	13	11	6	8
	12	14	4	10	16	13	2	6	14	13	4	5	12	12	6	12
	13	11	6	9	18	15	3	7	14	13	4	7	14	14	2	9
	11	11	8	14	9	13	9	15	11	16	4	10	8	8	14	15
	9	13	8	10	13	15	3	12	13	16	2	13	23	6	1	2
	11	15	4	7	23	6	2	9	13	15	3	7	15	9	6	11
	19	7	4	10	12	13	6	10	18	8	5	5	12	10	8	12
	8	15	7	10	15	13	8	13	11	15	5	8	17	8	5	10
	12	15	3	11	17	10	4	10	12	16	3	10	14	11	5	12
	9	11	11	19	12	12	7	17	17	13	1	9	10	10	10	15
	8	10	12	10	18	18	3	12	12	10	9	10	13	15	2	10
ge for 34 years.	10	12	8	13	12	13	6	11	13	12	6	9	12	10	8	10

Year.	October.				November.				December.				Year.			
	Clear.	Partly cloudy.	Cloudy.	Rain.	Clear.	Partly cloudy.	Cloudy.	Rain.	Clear.	Partly cloudy.	Cloudy.	Rain.	Clear.	Partly cloudy.	Cloudy.	Rain.
	9	12	10	18	11	12	7	14	6	11	14	14	134	131	100	153
	16	6	9	5	10	3	17	11	2	6	23	13	119	89	157	134
	13	6	12	8	8	12	10	13	8	7	16	12	131	109	126	135
	9	9	13	15	8	8	14	17	4	8	19	15	99	112	154	146
	7	15	9	11	6	6	18	8	4	13	14	10	103	108	139	148
	7	12	12	13	3	14	13	11	1	14	16	20	64	174	127	179
	7	13	11	14	3	7	20	16	3	17	11	15	75	145	146	181
	9	7	15	14	5	4	21	17	6	3	22	14	123	91	151	152
	9	6	16	13	8	6	16	10	2	0	29	19	93	78	194	157
	7	7	17	6	6	8	16	16	2	3	26	19	103	66	196	145
	11	4	16	11	4	9	17	10	0	3	28	14	97	74	195	148
	7	5	19	14	3	4	23	14	5	6	20	14	95	82	188	150
	13	9	9	19	3	9	18	13	2	5	24	18	78	99	188	165
	3	12	16	15	5	8	17	11	3	9	19	14	79	144	142	162
	12	11	8	10	7	11	12	10	4	7	20	21	100	122	144	150
	8	7	16	13	1	8	21	18	3	10	18	17	91	138	186	163
	15	9	7	8	7	7	16	13	7	14	10	15	105	146	114	153
	8	11	12	12	10	9	11	10	5	11	15	15	102	139	124	150
	8	5	13	14	9	7	14	12	6	6	19	12	107	125	129	150
	9	11	11	7	4	6	20	17	5	12	14	17	103	129	133	140
	2	10	19	17	6	12	12	11	5	12	14	9	93	140	132	154
	10	13	8	10	3	10	17	18.	7	14	10	14	87	157	121	158
	8	16	7	7	1	9	20	16	1	12	18	13	74	140	152	166
	14	11	6	9	7	9	14	12	2	15	14	19	91	134	134	161
	7	12	12	17	8	9	13	14	7	8	16	14	110	143	112	154
	16	12	3	7	5	9	16	13	6	9	16	16	128	137	100	128
	14	9	8	7	3	12	15	14	3	13	15	13	97	136	133	151
	11	15	5	8	1	15	14	15	2	9	20	15	102	137	126	147
	4	13	14	16	6	11	13	12	6	8	17	11	113	122	130	142
	11	11	9	9	5	12	13	9	6	12	13	18	112	134	119	141
	17	10	4	8	4	8	18	17	5	12	14	14	117	132	116	150
	15	12	4	8	2	16	12	10	7	8	16	10	110	128	127	146
	9	15	7	11	8	10	12	12	6	7	18	17	104	146	105	153
	15	9	7	7	9	9	12	9	4	12	15	15	112	132	121	135
age for 34 years.	10	10.	11	11	6	9	15	13	4	9	18	15	102	124	139	151

TABLE 11.—*Miscellaneous meteorological and phenological data.*

Year.	Date of frost.				Freeze.		Harvest began.	
	Last killing.	First killing.	Last light.	First light.	Last.	First.	Wheat.	Oats.
1870	Apr. 26	Oct. 14	May 28	Sept. 12	Apr. 26	Oct. 19	....	....
1871	May 10	Sept. 21	June 30	Sept. 8	May 10	Sept. 22	....	....
1872	May 14	Sept. 28	May 14	Aug. 31	May 4	Sept. 28	July 10	July 29
1873	May 4	Sept. 20	June 1	Aug. 18	Apr. 25	Sept. 21	July 8	Aug. 2
1874	May 19	Sept. 21	July 22	Sept. 21	May 19	Sept. 21	July 3	July 23
1875	May 17	Sept. 18	May 18	Aug. 24	May 17	Sept. 21	July 19	July 29
1876	May 11	Oct. 5	May 24	Aug. 21	May 1	Oct. 9	July 11	July 31
1877	May 3	Oct. 6	June 23	Sept. 18	May 2	Oct. 22	July 9	July [illegible]
1878	May 13	Oct. 6	May 22	Aug. 26	May 13	Oct. 19	July 9	July [illegible]
1879	May 8	Sept. 19	June 7	Aug. 18	May 3	Sept. 25	July 7	July [illegible]
1880	May 1	Sept. 30	May 15	Sept. 14	Apr. 12	Oct. 18	July 2	July [illegible]
1881	Apr. 30	Oct. 5	May 3	Sept. 12	Apr. 30	Oct. 19	July 7	Aug. 1
1882	May 24	Oct. 10	May 25	Sept. 24	May 24	Oct. 19	July 11	Aug. 4
1883	June 1	Sept. 9	June 14	Sept. 9	May 13	Sept. 9	July 13	Aug. 14
1884	May 29	Sept. 21	May 29	Sept. 19	May 29	Sept. 21	July 10	July 25
1885	May 11	Sept. 2	June 9	Sept. 2	May 11	Sept. 2	July 14	Aug. 4
1886	May 17	Oct. 1	June 4	Aug. 3	May 16	Oct. 1	July 1	July 22
1887	Apr. 24	Sept. 17	Apr. 25	Aug. 25	Apr. 24	Sept. 24	June 28	July 16
1888	May 20	Sept. 14	June 4	Aug. 23	May 20	Sept. 14	July 10	July 31
1889	May 28	Sept. 21	June 4	Sept. 7	May 28	Sept. 22	July 13	Aug. 8
1890	May 11	Sept. 21	May 11	Aug. 23	May 11	Oct. 21	July 5	July 15
1891	May 27	Oct. 6	May 27	Aug. 29	Apr. 9	Oct. 6	July 2	July 27
1892	May 8	Oct. 5	May 28	Sept. 6	May 8	Oct. 5	July 5	Aug. 4
1893	May 19	Sept. 17	May 24	Aug. 30	May 8	Sept. 26	July 2	July 21
1894	May 28	Sept. 25	June 6	Aug. 4	Apr. 13	Sept. 25	July 1	July 18
1895	May 22	Sept. 24	May 22	Sept. 1	May 22	Oct. 1	June 26	July 18
1896	Apr. 22	Sept. 21	Apr. 22	Sept. 21	Apr. 8	Sept. 21	June 23	July 13
1897	May 31	Sept. 21	June 9	Aug. 20	Apr. 21	Sept. 21	July 8	July 24
1898	May 6	Oct. 15	May 9	Sept. 12	Apr. 27	Oct. 27	July 1	July 20
1899	Apr. 10	Sept. 14	May 20	Sept. 13	Apr. 10	Sept. 30	July 4	July 18
1900	May 10	Oct. 11	May 20	Oct. 9	May 10	Oct. 17	June 29	July 21
1901	May 15	Sept. 19	June 9	Sept. 18	May 13	Sept. 19	July 6	July 18
1902	May 15	Sept. 14	June 24	Aug. 12	May 15	Oct. 29	July 9	July 25
1903	May 4	Oct. 18	May 4	Sept. 6	May 4	Oct. 21	July 6	July 25
Mean	May 12	Sept. 25	May 29	Sept. 2	May 5	Oct. 2	July 6	July 26

Year.	Leaves changed color.		Corn ripe.	Last snow.	First snow.	Number days from—			Annual range of temperature.
	Maple.	Red oak.				Last hard frost to first hard frost.	Last freeze to first freeze.	First freeze to last freeze.	°
1870	....	....	....	Apr. 13	Nov. 18	171	176	....	109.0
1871	....	....	....	Apr. 29	Nov. 6	134	135	204	122.0
1872	....	....	....	Apr. 15	Oct. 13	137	147	225	118.8
1873	....	....	....	Apr. 24	Oct. 21	139	149	219	124.5
1874	....	....	....	Apr. 30	Oct. 30	125	125	217	117.5
1875	....	....	....	May 2	Oct. 31	124	127	241	120.0
1876	....	....	....	Mar. 30	Oct. 24	147	161	239	106.0
1877	....	....	....	Apr. 30	Nov. 5	156	173	205	109.0
1878	....	....	....	May 10	Nov. 27	146	159	193	107.0
1879	....	....	....	Apr. 15	Nov. 2	134	145	207	118.0
1880	....	....	....	Apr. 30	Oct. 17	152	189	199	116.1
1881	....	....	....	Apr. 13	Nov. 3	158	172	195	115.5
1882	....	....	....	Apr. 26	Nov. 13	139	148	218	108.9
1883	Oct. 20	Oct. 5	Oct. 10	May 22	Nov. 12	100	119	207	110.5
1884	Sept. 24	Oct. 14	Sept. 15	Apr. 16	Oct. 23	115	115	262	127.7
1885	Oct. 15	Oct. 20	Sept. 30	May 9	Nov. 1	114	114	233	127.4
1886	Oct. 25	Oct. 24	Sept. 1	Apr. 7	Oct. 27	137	138	257	116.9
1887	Sept. 25	Oct. 15	Sept. 8	Apr. 27	Oct. 21	146	153	206	120.7
1888	Oct. 8	Oct. 21	Sept. 20	Apr. 20	Oct. 20	117	117	239	111.7
1889	Sept. 25	Oct. 24	Sept. 18	Apr. 6	Nov. 15	116	117	257	107.5
1890	Oct. 3	Oct. 26	Sept. 18	Mar. 29	Oct. 30	133	163	232	100.3
1891	Oct. 8	Oct. 7	Sept. 12	Apr. 6	Nov. 15	132	180	171	104.1
1892	Oct. 10	Oct. 18	Sept. 25	Apr. 14	Nov. 9	150	150	215	121.7
1893	Sept. 28	Oct. 17	Aug. 28	Apr. 22	Oct. 28	121	141	216	111.6
1894	Sept. 28	Oct. 15	Aug. 25	Apr. 5	Nov. 7	120	165	200	107.0
1895	Oct. 11	Oct. 11	Sept. 25	Apr. 2	Oct. 20	125	132	240	116.0
1896	Oct. 6	Oct. 6	Aug. 25	Apr. 9	Oct. 18	152	166	190	109.3

TABLE 11.—*Miscellaneous meteorological and phenological data*—Continued.

Year.	Leaves changed color.		Corn ripe.	Last snow.	First snow.	Number days from—			Annual range of temperature.
	Maple.	Red oak.				Last hard frost to first hard frost.	Last freeze to first freeze.	First freeze to last freeze.	
									°
7	Oct. 1	Oct. 3	Sept. 12	Apr. 11	Nov. 12	118	153	213	123.2
8			Aug. 29	Apr. 6	Nov. 10	132	183	218	108.3
9			Aug. 28	Apr. 1	Nov. 2	157	173	165	115.0
0			Sept. 3	Apr. 13	Nov. 7	154	160	223	104.5
1			Sept. 5	Apr. 21	Oct. 17	127	129	208	112.4
2			Sept. 3	Apr. 8	Nov. 26	122	167	238	104.7
3			Sept. 10	Apr. 22	Nov. 5	157	170	187	106.1
Mean			Sept. 19	Apr. 17	Nov. 2	135	150	216	113.5

TABLE 12.—*Dates of blossoming of apples, peaches, pears, plums, and cherries.*

Year.	Apples.	Peaches.	Pears.	Plums.	Cherries.
77	May 13	May 4	May 10	Apr. 29	May 6
78	Apr. 22	Apr. 12	Apr. 21	Apr. 13	Apr. 19
79	May 10	May 4	May 4		Apr. 28
80	May 4	Apr. 16	Apr. 28	Apr. 24	Apr. 24
81	May 9		May 9		May 8
82		Apr. 18			
83	May 17	May 13	May 9		May 9
84	May 13	May 4	May 8	May 8	May 6
85	May 18	None.	May 17	May 15	May 16
86	Apr. 25	Apr. 23	Apr. 25	Apr. 25	Apr. 23
87	May 10	May 3	May 6	May 2	May 4
88	May 11	May 6	May 8	May 10	May 7
89	May 8	Apr. 23	May 4	May 4	Apr. 27
90	May 12	Apr. 16	May 2	Apr. 30	May 1
91	May 6	Apr. 23	Apr. 30	Apr. 28	Apr. 28
92	May 15	May 7	May 12	May 8	May 5
93	do	May 10	do	May 10	May 8
94	May 2	Apr. 17	Apr. 26	Apr. 25	Apr. 24
95	May 6	May 2	May 3	May 1	May 2
96	Apr. 27	Apr. 21	Apr. 25	Apr. 22	Apr. 24
97	May 9	None.	May 8	May 9	May 5
98	May 4	Apr. 22	Apr. 29	Apr. 29	Apr. 22
99	May 1	Apr. 28	do	do	Apr. 27
00	May 9	Apr. 29	May 7	May 1	May 1
01	May 10	do	May 3	Apr 30	May 3
02	May 5	do	Apr. 30	Apr. 29	Apr. 29
03	Apr 29	Apr. 26	Apr. 29	Apr. 26	do
04	May 14	May 7	May 8	May 5	May 7
Average	May 7	Apr. 28	May 8	May 1	May 1

TABLE 13.—*Yield of crops per acre in Fulton County, Ohio, as published in t annual reports of the secretary of state, from the assessors' returns.*

Year.	Wheat.	Corn.	Oats.	Barley.	Rye.	Potatoes.	Fruit.[a]	Hay.[b]	Clov
	Bushels.	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Tons.*	*Ton*
1874	15.0	40.0	35.9	15.5	16.5	76	35	1.02	1
1875	9.0	53.2	29.6	24.2	13.0	98	25	1.20	1
1876	9.9	20.0	23.3	21.4	9.6	36	76	1.33	1
1877	18.4	35.6	35.6	12.1	9.5	103	7	1.21	1
1878	18.2	46.4	33.1	21.2	13.9	76	66	1.26	1
1879	19.6	43.0	36.3	30.2	12.5	95	31	1.18	1
1880	17.6	35.7	30.1	29.2	14.5	87	71	1.20	1
1881	14.2	34.9	31.9	13.3	8.0	92	38	1.17	1
1882	14.1	40.1	28.8	31.6	14.3	96	35	1.26	1
1883	17.2	13.0	33.5	18.1	14.5	113	30	1.37	1
1884	16.2	39.4	38.4	15.2	10.7	109	29	1.27	1
1885	15.7	30.0	28.3	16.3	9.2	103	17	1.24	1
1886	17.2	34.4	43.3	23.9	14.8	100	77	1.08	
1887	16.8	32.8	35.1	31.5	14.0	50	23	1.29	1
1888	19.8	40.2	41.1	27.4	16.6	102	43	1.18	1
1889	16.9	41.7	35.9	31.6	14.3	95	52	1.24	1
1890	16.4	31.0	31.0	21.5	11.0	83	5	1.31	1
1891	21.0	36.4	37.8	27.0	15.4	133	26	1.36	1
1892	15.6	20.7	26.2	15.8	7.9	59	8	1.43	1
1893	18.4	32.1	36.1	26.5	14.6	114	3	1.41	1
1894	19.0	28.4	32.7	40.0	14.8	65	22	1.34	1
1895	15.2	21.7	36.1	24.2	14.3	90	25	.84	
1896	11.4	39.3	30.9	17.3	10.1	73	69	1.34	1
1897	16.7	35.6	34.9	14.4	14.7	75	13	1.34	1
1898	19.1	41.6	20.6	27.9	13.3	109	4	1.31	1
1899	3.1	40.0	45.9	32.1	12.8	107	34	1.28	1
1900	7.1	40.6	38.7	26.8	2.9	134	33	1.19	.1
1901	14.9	35.2	33.0	22.4	14.1	65	14	1.34	1
1902	15.5	34.5	42.5	30.5	14.1	105	49	1.39	1
1903	17.4	41.2	34.9	24.5	12.4	109	58	1.40	1
30 years	15.6	35.3	34.0	23.8	12.6	92	34	1.26	1

[a] Apples, peaches, pears, cherries, plums.

[b] Meadows other than clover.

TABLE 14.—*Number of acres in orchards and total yield of fruit in Fulton Coun Ohio.*

Year.	Acres in orchards.	Total yield in bushels.				
		Apples.	Peaches.	Pears.	Cherries.	Plu
1874	4,324	141,819	9,395	671	----------	----
1875	4,867	122,363	0	145	----------	----
1876	4,590	337,946	761	467	----------	----
1877	5,134	33,920	577	649	----------	----
1878	5,138	337,082	1,468	381	----------	----
1879	5,150	155,480	1,699	436	----------	----
1880	5,694	393,390	7,141	710	918	
1881	5,266	199,178	473	552	379	
1882	5,163	174,813	5,102	572	68	
1883	5,253	160,048	58	461	35	
1884	5,598	162,082	0	279	810	
1885	5,075	87,333	300	220	59	
1886	4,780	367,731	436	1,200	1,073	
1887	4,758	107,213	663	1,712	30	
1888	4,574	197,300	410	781	202	
1889	4,619	227,315	1,853	3,236	5,732	
1890	5,006	23,564	320	744	336	
1891	5,689	129,611	7,869	5,012	2,482	
1892	4,654	36,655	100	432	109	
1893	4,465	10,062	1,540	1,308	135	
1894	4,525	96,012	1,980	1,980	525	
1895	4,605	95,439	6,512	13,765	1,298	
1896	4,600	307,037	9,157	1,849	448	
1897	4,077	53,327	2	636	295	
1898	3,612	5,223	4,863	2,293	580	
1899	3,180	106,173	750	294	296	
1900	3,498	113,122	1,509	468	39	
1901	3,442	43,202	3,059	733	246	
1902	3,297	157,733	3,436	1,259	79	
1903	2,639	153,339	1,425	391	32	

DISCUSSION.

Mr. **Scarr**. I can not let this paper pass without inviting attention to the opening of what seems to be a most valuable field of research and usefulness. If the time ever comes (and it may come sooner than we think) that the Weather Bureau is able to make accurate seasonal forecasts we shall have urgent need for just such facts as this compilation shows, and now while the system of forecasting is developing is the time to gather and discuss these phenological data. The forecast will reveal the conditions likely to prevail during the approaching season, and the diagram will show the crops best adapted to those conditions and the most advantageous time for planting, harvesting, etc.

I would like to ask if the present study shows any apparent order or relation to exist between the conditions prevailing in autumn, winter, spring, and summer, respectively, that would be of value in determining before the time of planting the probable yields of different crops, or the best time for planting them.

Mr. J. **Warren Smith**. I would answer that by repeating what I have already said, that I have not attempted to follow out any of the lines that can be started from this, but that you or anybody interested can follow out the lines of study for which I have not had time.

Mr. **Jennings**. I confess to a great deal of interest in Mr. Smith's statement. The conditions regarding the oat crop seemed to govern Kansas as well, but our corn yield differed somewhat. We have found that the yield of corn in Kansas depends not so much upon the amount of rainfall as it does upon the temperature. A cool July and August give us the largest yields, but a hot July or August is liable to shorten the crop very much, no matter what the rainfall is.

Professor **Abbe**. A great deal depends upon the soil. A very hot climate and dry winds will dry the soil very quickly and the plant loses its sap. I am sure these observations ought to be published in full. The whole question of phenology seems to be obscure and we owe it to ourselves to study it. I think all our men could do better work by starting intelligent farmers to making these observations and collecting the data for study.

Professor **Garriott**. The value of the seasonal forecasts will be found in the use that is made of them in governing growing crops. A great deal of work is now being done in this direction. Of course we can not tell what the future may bring forth, but I think the outlook is very favorable for discovering something in that line. We are on the eve of some discoveries. I am satisfied of that.

Mr. **Berry**. At the Milwaukee convention the matter of phenological records received some consideration. I believe that the published report of its proceedings will show that Mr. Smith took active part in the discussion of the subject. The paper just read certainly is an assurance of his continued interest and fully emphasizes the importance of information of this character. Unfortunately for those who may wish to engage in similar studies, it must be remembered that records such as those kept by Mr. Mikesell are very rare, and it is probable that in very few States can be found data in sufficient detail to afford a basis for satisfactory treatment.

The officials in charge of the Climate and Crop Service are now devoting especial attention to the subject of phenological observations. In the early part of this year, for the first time in the history of the Weather Bureau, definite efforts were made to encourage the taking of phenological observations. After inviting suggestions from the various section directors of the Climate and Crop Service, a blank form (see Exhibit A) was prepared and given general distribution in March. The results of the efforts in this direction will undoubtedly increase the interest in the subject. Not only will many of our voluntary observers take up the work of recording phenological data, but it is quite probable that records, of whose existence we are not aware, will be discovered.

I think that it is quite probable that the attention devoted to the subject of phenological observations at the Milwaukee convention led to the disclosure of the valuable record kept by Mr. Mikesell at Wauseon, Ohio.

EXHIBIT A.

orm No. 1012—Met'l.]

U. S. DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

VOLUNTARY OBSERVER'S PHENOLOGICAL RECORD FOR THE YEAR 19—.

ation, ——; County, ——; State, ——; Latitude, ——; Longitude, ——; Elevation, —— feet above sea level.

Dates of observed phenomena.

FOREST TREES.

Kind.	First leaves.	Woods green.	Leaves coloring.	Leaves falling.	Woods bare.	General remarks.

ORCHARD TREES, VINES, AND SHRUBS.

Kind.	First leaves.	First bloom.	Full bloom.	Period of harvest.		Character of yield.		General remarks.
				Begins.	Ends.	Quantity.	Quality.	
pple								
each								
ear								
lum								
herry								
trawberry								
lackberry								
aspberry								
uckleberry								
rape								

CEREALS, GRASSES, VEGETABLES, ETC.

Kind.	Preparation of soil.		Planting.		Special stages of development.	Period of harvest.		Character of yield.		General remarks.
	Begins.	Ends.	Begins.	Ends.		Begins.	Ends.	Quantity.	Quality.	
orn										
heat										
ats										
arley										
ye										
uckwheat										
ice										
ugarcane										
otton										
obacco										
imothy										
lover										
lfalfa										
rish potatoes										
weet potatoes										
omatoes										
elons										

MISCELLANEOUS NOTES.

(See instructions on back of form.)

——— ———, Voluntary Observer.

EXHIBIT A—Continued.

U. S. DEPARTMENT OF AGRICULTURE,

WEATHER BUREAU.

VOLUNTARY OBSERVER'S PHENOLOGICAL RECORD

AT

For the year ______________________________

INSTRUCTIONS.

1. Notes on forest trees will embrace three well-known varieties which, for the sake of uniformity in record, will be selected by the section director. The first will be one that puts forth its leaf very early in the season; the second, one that shows leaf at about an average date; and the third, a variety noted for its tardiness in coming into foliage.

2. Weather conditions of a decidedly beneficial or injurious character, the prevalence of insect enemies or fungi, and other features that have had a special bearing upon growth or yield, will be briefly noted under "General remarks."

3. Information not adapted to general classification will be entered under the heading, "Special stages of development." This will include dates of stooling, jointing, blossoming, and heading for crops to which such terms apply. Special record will be made of dates of silk, tassel, and roasting-ear stage in corn; first squares and first bolls in cotton; and transplanting, buttoning, and topping in tobacco. Many minor crops will also call for special notes, the nature of which will become apparent with the advance of the season.

4. In the columns for "Character of yield," the quality and quantity will be described by the expressions "excellent," "good," "fair," or "poor," as the case may require.

5. When two or more crops of a given product are raised, such as winter and spring wheat, or two or more harvests are obtained, as with alfalfa, the several crops and yields should be described separately.

6. Miscellaneous notes may include dates of migration of birds, swarming of bees, appearance and disappearance of hibernating animals, first croaking of frogs, and other items of interest not provided for elsewhere.

7. This form should be mailed to the section center after the final entries for the season have been made. A copy may be retained by the voluntary observer, if desired.

WILLIS L. MOORE,
Chief U. S. Weather Bureau.

A STUDY OF THE RAINFALL ON THE WEST FLORIDA COAST.

By Mr. B. BUNNEMEYER, *Providence, R. I.*

During the past spring the rainfall data of the Pensacola station, covering a period of twenty-four years from January 1, 1880, to January 1, 1904, have been studied with a view to determining, if possible, the most favorable time for the formation of rainstorms and the relation of precipitation to temperature. The results of this investigation are given herewith, from which the reader may draw his own conclusions. Reference should be had to the figures and tables accompanying this article.

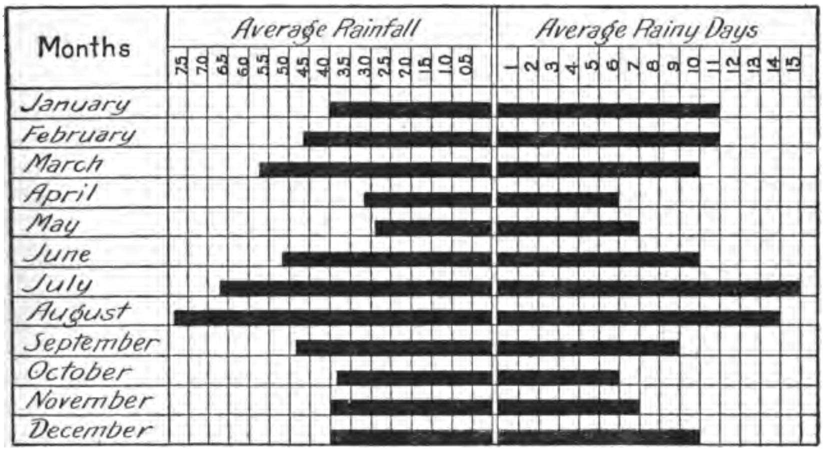


FIG. 1.—Average monthly rainfall and average monthly number of rainy days.

During the past twenty-four years 5,101 separate rainstorms occurred, which yielded an average annual rainfall of 57 inches, occurring on an average of 116 days per annum. The heaviest annual rainfall was that of 1881, and amounted to 86 inches, and the least that of 1891, when only 35.6 inches fell; but the wettest year had a deficiency of nearly 2 inches in March and May and of about 1 inch in June and July, while the driest year had an excess of over 2 inches in March and a very slight excess in January.

An examination of figure 1 shows that the average number of rainy days varies almost directly with the average amount of rainfall, and both in general have their most value during the late spring and their greatest during midsummer. The maximum monthly precipitation occurs during August with an average of 7.9 inches, and the minimum during May, with an average of 2.9 inches. A secondary maximum occurs during March, with an average of 5.7 inches, and a secondary minimum during October, with an average of

3.8 inches. The months of July and August are preeminently the wettest of the year, with a total average of 14.6 inches, and the months of April and May the driest, with a total average of 6.1 inches. The winter months receive very nearly their proportion of the annual rainfall.

The difference in the number of rainstorms occurring during the day and during the night is quite decided. Of the 5,101 rainstorms during the past twenty-four years 3,113, or 60 per cent, began during the daytime, and 1,988, or 40 per cent, during the nighttime. The monthly averages are shown in figure 2, from which it appears that the chances in favor of day rainstorms over night rainstorms are greatest in July and least in April and October. The relation of day rainstorms to night rainstorms for the various months, expressed in percentage, is as follows:

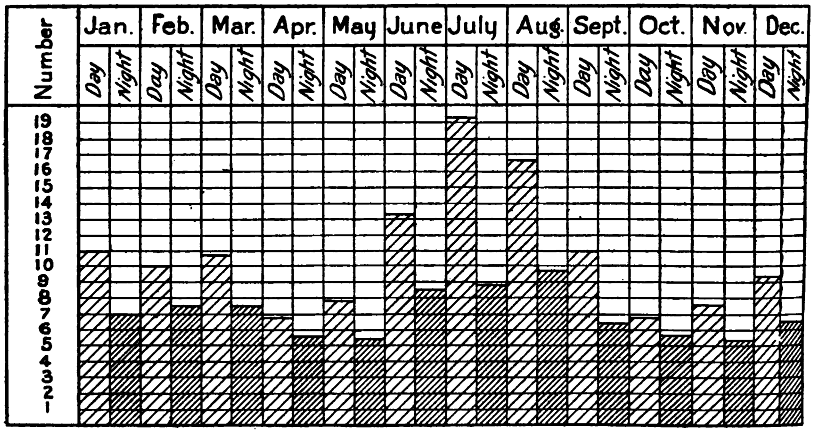


FIG. 2.—Average number of rainstorms beginning during the day (8 a. m. to 8 p. m.) and during the night (8 p. m to 8 a. m.).

Month.	Day showers.	Night showers.	Month.	Day showers.	Night showers.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
January	58	42	August	63	37
February	58	42	September	63	37
March	59	41	October	56	44
April	56	44	November	59	41
May	60	40	December	59	41
June	61	39			
July	69	31	The year	60	40

An attempt was made to determine the average hourly fluctuations of showers, but the frequent entries "begun during night" frustrated the attempt for the nighttime. For the daytime there is a general increase in the frequency of showers from 8 a. m. to 1 p. m., and a gradual decrease with minor fluctuations from 1 p. m. to 8 p. m. For the several months the greatest and least hourly frequency of showers between 8 a. m. and 8 p. m. is as follows:

Month.	Greatest.	Least.
January	2 p. m. to 3 p. m.	9 a. m. to 10 a. m.
February	3 p. m. to 4 p. m.	5 p. m. to 6 p. m.
March	1 p. m. to 2 p. m.	5 p. m. to 6 p. m.
April	3 p. m. to 4 p. m.	8 a. m. to 9 a. m.
May	11 a. m. to noon	9 a. m. to 10 a. m. 4 p. m. to 5 p. m.
June	Noon to 1 p. m.	7 p. m. to 8 p. m.
July	10 a. m to 11 a. m.	7 p. m. to 8 p. m.
August	4 p. m. to 5 p. m.	7 p. m. to 8 p. m.
September	2 p. m. to 3 p. m.	9 a. m. to 10 a. m.
October	8 a. m. to 9 a. m.	4 p. m. to 5 p. m.
November	7 p. m. to 8 p. m.	10 a. m. to 11 a. m.
December	8 a. m. to 9 a. m.	9 a. m. to 10 a. m.

It may be interesting to note that the average amount of rainfall per shower ranged from 0.21 for January to 0.32 for March, while the average per rainy day ranged from 0.36 for January to 0.63 for October.

Excessive precipitation of 2.50 inches or more during any consecutive twenty-four hours has occurred during all months; but most frequently in August, with 13 counts, and least frequently in January, with 3. Next to August, the months of July, October, and March show the greatest number of excessive precipitations, in the order named.

The relation of rainfall to temperature is shown in the accompanying table, which expresses in figures the number of times a normal, excessive, or deficient precipitation occurred with similar conditions of temperature for each month, season, and year. Two hundred and eighty-eight months are covered by this exhibit, and of this number 68 showed an excessive temperature with a deficient precipitation; 66, a deficient temperature with an excessive precipitation; 58, a deficient temperature with a deficient precipitation, and 35, an excessive temperature with an excessive precipitation. These combinations also predominated in almost similar proportions for the four seasons. By years, however, there were 7 that had a normal temperature with excessive precipitation; 5, a normal temperature with deficient precipitation, and 5, a deficient temperature with deficient precipitation.

No periodicity of precipitation could be discovered. The seven years from 1880 to 1886 had an excess of precipitation, and the seven years from 1889 to 1895 had a deficiency, while the eight years from 1896 to 1903 alternated in excess and deficiency; and similar conditions were found to exist for the seasons and months.

The conditions most favorable for the production of precipitation, as depicted on the morning weather map, are generally well recognized; but there is one phase of weather conditions that occurs mostly during the warm season and deserves mention as a fairly reliable forerunner of local disturbances. If the morning weather map is flat, and neighboring stations show minor differences of 0.02 inch or more in pressure without a well-defined or regular increase or decrease in any direction, showers very frequently follow during the afternoon or night, although fair weather prevails at the time. Such minor differences in pressure, when they occur between isobars where they are seemingly out of place and not expected, are always significant and frequently the only indication of approaching local disturbances, especially if the temperatures are above normal.

Table showing number of months, seasons, and years, with temperature and rainfall normal, excessive, and deficient, 1880–1904.

[Period, January 1, 1880, to January 1, 1904.]

	Temperature normal.			Temperature excessive.			Temperature deficient.		
	Rainfall normal.	Rainfall excessive.	Rainfall deficient.	Rainfall normal.	Rainfall excessive.	Rainfall deficient.	Rainfall normal.	Rainfall excessive.	Rainfall deficient.
Months.									
January	0	0	1	1	2	6	2	5	7
February	0	1	0	1	2	8	0	5	7
March	0	2	1	1	5	3	0	6	6
April	0	1	2	0	4	6	1	5	5
May	0	1	2	0	2	7	0	7	5
June	0	1	5	0	0	7	0	6	5
July	0	7	1	1	1	8	0	3	3
August	1	1	3	0	5	5	0	5	4
September	1	1	5	1	4	3	2	3	4
October	0	0	2	0	3	4	0	10	5
November	0	1	2	1	3	6	1	6	4
December	0	0	3	0	4	5	4	5	3
Total	2	16	27	6	35	68	10	66	58
Seasons.									
Spring	1	2	0	1	2	8	0	2	8
Summer	0	2	1	0	4	3	2	6	6
Fall	0	3	6	0	3	4	0	4	4
Winter	0	0	1	1	4	5	1	7	5
Total	1	7	8	2	13	20	3	19	23
Years	0	7	5	0	2	2	0	3	5

DISCUSSION.

Mr. **Mitchell**. Broadly speaking along the line Mr. Bunnemeyer referred to, 75 per cent of our summer rains in Florida occur in the daytime. I tabulated that some time ago, and that was the result. I may say that in 90 per cent of the cases of rainfall in the morning observation it will be safe to forecast clear weather for the night. On the average, we are safe in concluding that 75 per cent of the rainfall occurs during the day in summer months. The percentage increases beginning with September. It is a fact to be kept well in mind in forecasting precipitation for Florida during the summer months, and I think it largely obtains throughout the lower South Atlantic and Gulf coasts.

Major **Bate**. Is not that more peculiar to the peninsular part of Florida?

Professor **Garriott**. My experience with the forecast has been that that is a condition peculiar to the peninsular part of the State, including Jacksonville. I do not think it is true to quite that extent at Pensacola; still it is true, as Mr. Bunnemeyer's figures show, at Pensacola also. But forecasters have learned by experience to put showers in Florida every afternoon in summer time.

Mr. **Bauer**. In that connection I have noticed that the percentage is very much larger, probably twice as large, in the interior of South Carolina, and I suppose along the line where the low country merges into rolling land; but there are exceptional years. Along the coast the ratio is more fixed and steady. In the interior and upper parts of the State it varies greatly.

CLIMATOLOGY OF PORTO RICO.

By Mr. W. H. Alexander, *Galveston, Tex.*

The topography of Porto Rico is indeed a puzzle—a sort of orographic kaleidoscope presenting new scenes at every turn. It must be seen to be understood and appreciated. So far as my knowledge and experience go, all "pen pictures" are imperfect and therefore unsatisfactory. For this reason one very naturally hesitates in an attempt to do what other and abler writers have apparently failed to do, seeing that but slight improvement at best can be hoped for and perchance only another may be added to the long list of failures. However, the importance of the physical features of the island as factors in its climatology demands at least an effort in this direction. The topography is the one factor which gives to the climatology of Porto Rico its surprising variety. Eliminate this and you at once reduce the problem to one whose factors are comparatively simple both singly and in combination. There is, perhaps, no portion of the earth where the principles, or theories, if you please, of meteorology are more simply and uniformly demonstrated than in the Tropics. There the climatic elements are comparatively simple and monotonously uniform in their operations.

As everyone knows, Porto Rico is situated well within the Tropics, being in about 18° north latitude, is more or less rectangular in form, the greater axis extending east and west, is about 100 miles long, and about 36 miles wide, and therefore contains about 3,600 square miles, or is about three times the size of the State of Rhode Island. The surface is exceedingly rough and broken, the hills and mountains being indiscriminately heaped together. There is, however, a well-defined watershed extending from the northeast to the southwest corner of the island, closely paralleling the southern and eastern coast lines and so dividing the island that about one-third of it is south of the divide and two-thirds north. This ridge varies in elevation from about 2,000 feet to something more than 3,000 feet, and is deeply corrugated on both sides by gorges and hills, thus giving rise to an astonishingly large number of streams, some of which are rivers of no mean proportions. Of course the streams on the south side are very short and precipitous, while those on the north side find their way to the sea along more gently inclined courses.

The peculiar topography of the island and its position with reference to the prevailing trade winds give to it very decided and important local climatic differences. For example, the range in the annual rainfall in this small territory is quite as great as that of the entire United States. The effects are at once apparent in the vegetation of the north and south sides of the island; on the north side the vegetation is found in all its tropical luxuriance, while on the south side semiarid plants largely predominate. The dry, stony river beds of the south side stand in marked contrast to the ever-flowing, bounding streams of the north side. It therefore appears that Porto Rico has a wet and a dry side more marked than the so-called wet and dry seasons, as commonly understood by these terms.

The temperature changes, both daily and annual, when expressed in figures appear to be insignificant, but to the native or to one acclimated they are very appreciable, so much so that the expression "rigors of winter" is sometimes heard, and not altogether inappropriately. As elsewhere, the minimum temperature for the day usually occurs shortly before sunrise and the maximum near midday. The temperature rises very rapidly between sunrise and 10 a. m., remains practically stationary from 10 a. m. to 2 p. m., and then falls gradually until the early morning of the following day. The range is quite constant throughout the year, but varies at different places over the island, depending upon the location and the local surroundings. The mean daily range at San Juan, for example, is between 11° and 12°, but there is less than 2° difference between the mean range for the various months. Some mountain stations have a daily range of 20° or more.

Figure 1 shows the departures of monthly mean maximum and monthly mean minimum temperatures from the annual mean temperature at San Juan, Porto Rico.

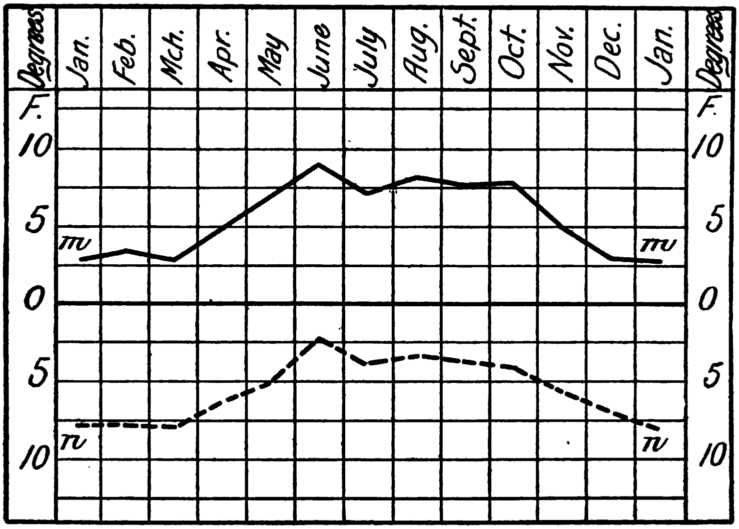


FIG. 1.—Line 00, annual mean (78°.6); mm, mean maximum; and nn, mean minimum.

The month of January has the lowest mean temperature, while the means of February and March are but slightly higher. The mean temperature gradually increases from March to August and then begins to decrease. Although August has the highest mean temperature, September has the highest mean maximum temperature. Note also that there is a difference of only about 5° between the highest and the lowest monthly means. A temperature of 100° is very rare, but does sometimes occur, while a temperature of 50° has been reported from interior stations, thus indicating an absolute range for the island of about 50°. This of course precludes the possibility of frost in Porto Rico, at least within the range of observation, and the occurrence of even light frost on the summits of the highest mountains is extremely improbable. The writer made a journey to the summit of El Yunque, the highest mountain on the island, on the 22d of February, 1903, and there was not the slightest indication of frost observed, but on the other hand the very tenderest vegetation was found almost to the summit.

Rainfall in Porto Rico is very frequent, almost daily, but it usually comes in quick, sharp showers, generally light, but sometimes quite heavy. A long series of wet, dreary days is unknown in Porto Rico, the precipitation being almost entirely due to convectional processes. The rainfall is about equally divided between day and night, but the excessive falls usually occur during the day. Thunderstorms are not as frequent nor as violent as one might reasonably suppose.

The distribution of rainfall throughout the year is quite simple and very uniform. All inspection of the monthly averages for any one station will show that January, February, and March constitute what is commonly meant by the dry season, as these months have considerably lower means than the others. The average for these three months at San Juan, for example, is 7.66 inches, which is but little more than the average for the month of November. After March there is a gradual increase in the monthly averages until November is reached, after which there is a rapid decline. The so-called wet season extends from July to November, inclusive, during which time about 54 per cent of the total for the year falls.

Figures 2 and 3 show, respectively, the average monthly precipitation, in inches, at San Juan and Ponce, Porto Rico.

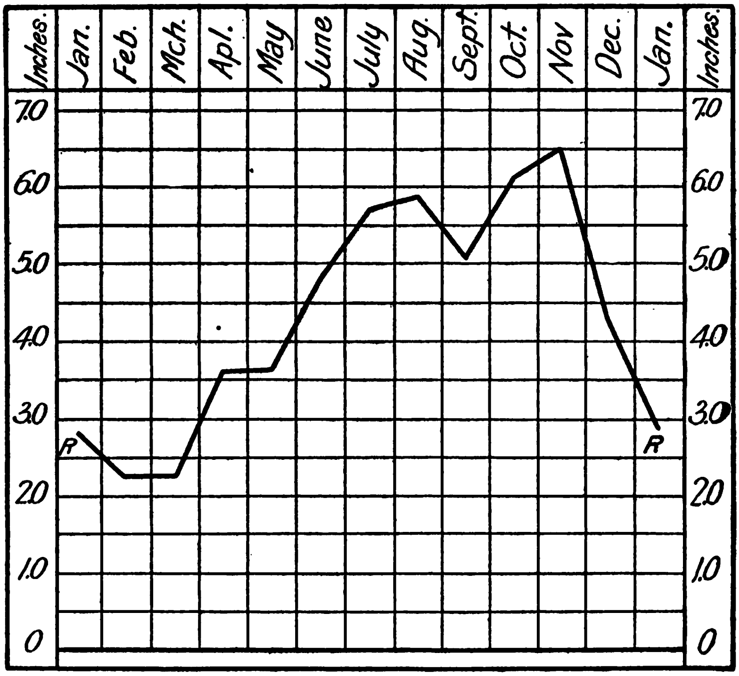


FIG. 2.—Average monthly precipitation, in inches, San Juan, Porto Rico.

After what has been said about the orography of the island, it is scarcely necessary to say that the rainfall is not evenly distributed ver the island. The heaviest fall occurs in the vicinity of El Yunue, in the northeastern portion, where it amounts to more than 150 nches annually. An annual fall of 100 inches or more is of common occurrence at interior stations situated on or near the divide. The fall gradually diminishes from the divide toward the north coast and is slightly less along the western half of the north coast. The average for a north coast station is about 55 inches. South of the divide the fall is not only much less, but is more erratic, long and severe droughts being so frequent as to render irrigation indispensable. The droughts seem to be most common and severe along the central portion of the south coast region.

The distribution of normal annual precipitation in Porto Rico is graphically shown in Chart I.

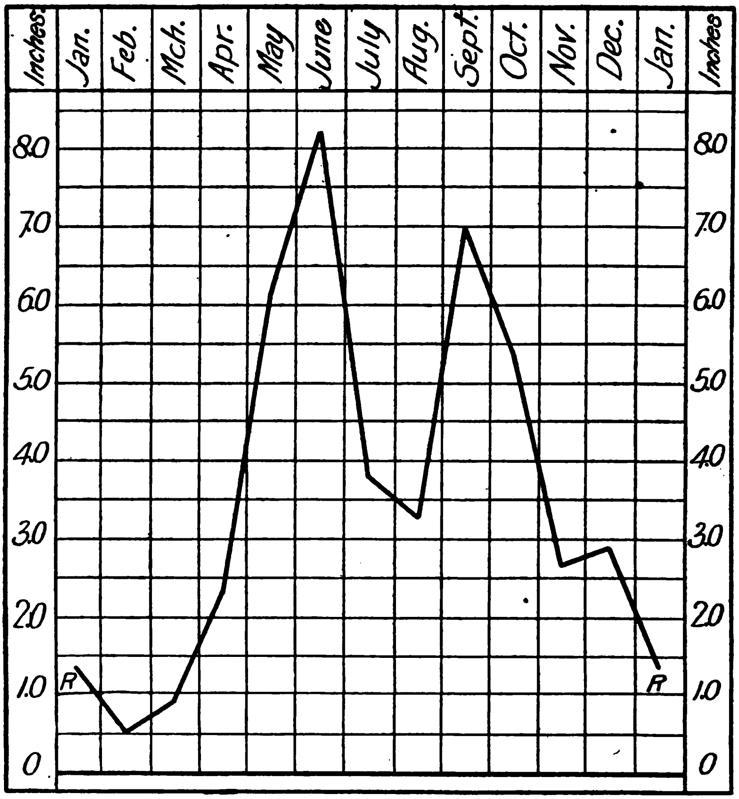
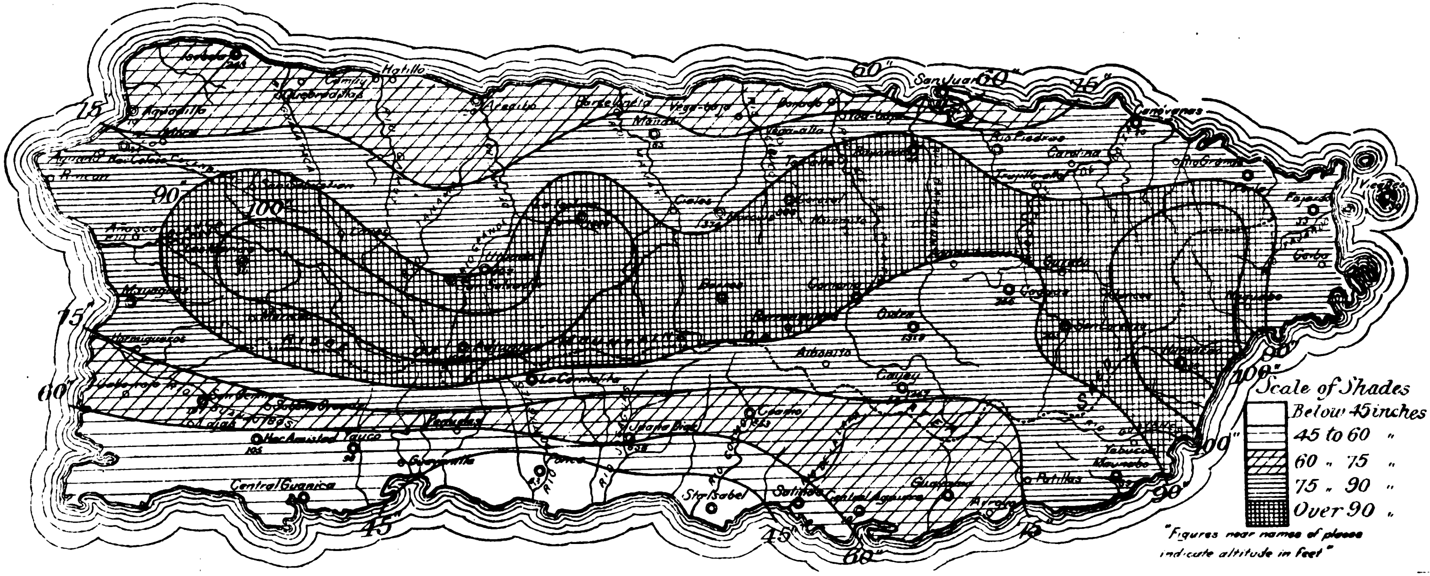


FIG. 3.—Average monthly precipitation, in inches, Ponce, Porto Rico.

The relative humidity of the atmosphere is at all times very high and is subject to the same daily changes as noted relative to the temperature, but, of course, in the reverse order. That is to say, the humidity is highest just before sunrise and decreases rather rapidly until midday and then increases again until the early morning of the next day. This constantly high humidity gives to the climate its very enervating effect.

The prevailing winds are easterly and are fresh to brisk during the day and light during the night. These are the trades, modified more or less by local conditions, and constitute one of the redeeming fea-

Chart I.—NORMAL ANNUAL PRECIPITATION, PORTO RICO.



THE NORRIS PETERS CO. PHOTO-LITHO. WASHINGTON D.C.

tures of the climate. The wind movement is greatest in March and least in October. The West Indian hurricanes, of course, constitute the great climatic misfortune of Porto Rico, but these are surprisingly rare, owing to the fortunate situation of the island with reference to the paths usually taken by these disturbances.

TABLE 1.—*Showing the average monthly and annual rainfall, in inches, for a number of stations in Porto Rico, based upon a record of five years.*

Station.	Altitude, in feet.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
North side.														
Adjuntas	1,968	4.38	0.86	2.68	7.29	10.92	12.66	9.99	16.89	10.92	11.79	8.79	4.15	101.32
Arecibo	20	5.01	.92	4.75	5.97	7.01	5.43	6.04	4.84	4.30	6.64	9.58	6.51	67.00
Barros	1,626	6.45	.81	2.50	2.98	23.30	8.72	8.28	3.40	6.62	11.40	12.92	4.30	91.68
Bayamon	76	4.66	.76	4.22	5.97	9.86	13.42	7.57	11.77	9.78	8.81	11.27	6.59	94.68
Caguas	246	6.02	1.23	2.17	6.22	6.09	12.33	10.90	5.93	6.61	10.74	6.98	4.60	79.82
Canovanas	20	4.82	1.87	2.79	5.46	7.11	6.95	10.87	7.86	7.06	5.79	10.80	6.98	78.36
Cayey	1,247	3.81	1.59	2.39	5.58	7.33	11.02	8.54	10.20	7.14	6.78	7.63	3.75	75.76
Cidra	1,312	5.50	.61	5.50	3.50	8.06	16.61	10.16	7.65	5.36	6.66	6.91	6.70	83.22
Corozal	364	5.90	1.84	5.14	8.46	12.17	8.49	12.43	6.86	8.67	11.98	11.62	6.00	99.56
Isabela	243	6.76	1.51	2.12	4.98	5.00	6.21	3.52	7.06	4.21	5.39	10.26	5.78	62.80
Isolina	1,400	6.12	1.05	5.78	5.81	18.01	9.24	6.62	9.41	11.50	10.47	10.71	6.69	101.41
Manati	85	4.38	1.03	5.45	5.85	6.79	7.29	8.00	6.29	7.64	6.76	11.48	5.44	76.32
Morovis	374	4.22	1.55	7.21	6.89	14.18	5.61	7.09	8.15	7.48	10.60	5.09	2.44	80.51
Perla	460	8.02	2.38	5.67	10.95	16.31	15.40	16.20	11.26	12.29	13.56	17.97	9.59	139.60
San Juan	82	2.97	2.37	2.32	3.59	3.67	4.87	5.74	5.89	5.13	6.18	6.50	4.30	53.53
San Lorenzo	203	3.96	1.39	3.64	6.01	7.14	20.46	10.18	8.84	9.84	9.29	7.51	4.71	92.97
San Salvador	1,200	3.45	.56	1.69	7.81	17.86	9.90	6.64	5.66	14.89	9.78	9.96	5.77	93.97
Utuado	427	3.08	.45	2.98	5.08	11.23	8.74	4.96	4.87	9.70	14.26	10.40	2.80	78.52
East side.														
Fajardo	33	4.48	.85	2.63	6.91	6.04	11.17	7.82	5.15	6.88	9.70	11.19	4.87	77.69
Humacao	59	6.01	1.07	3.04	7.84	14.66	18.91	10.02	9.06	10.30	10.14	11.67	4.60	107.32
Maunabo	39	6.08	1.86	2.94	3.79	9.22	17.21	8.81	5.79	8.05	10.52	9.67	5.56	89.50
South side.														
Aguirre	10	1.68	.94	.87	3.55	3.22	17.46	6.05	6.67	7.68	6.75	3.74	2.23	60.84
Coamo	853	2.60	.70	.93	3.90	7.89	10.76	5.27	6.00	6.07	7.90	7.85	7.81	67.18
Juana Diaz	656	2.40	.20	1.01	3.62	7.52	11.14	3.29	9.72	8.14	7.12	6.69	1.87	62.72
Ponce	43	1.33	.50	.87	2.33	6.15	8.27	3.80	8.32	7.08	5.31	2.69	2.93	44.53
St. Isabel	40	2.66	.34	.56	4.08	.45	8.96	3.64	2.84	6.68	5.67	5.32	3.26	44.46
Yauco	98	3.37	.56	2.54	3.20	5.36	9.93	6.38	3.41	5.64	4.27	4.08	2.01	50.75
West side.														
Aguadilla	20	3.86	.87	3.11	5.16	8.25	11.83	4.84	9.56	5.99	6.13	7.00	3.50	70.10
Coloso	34	3.68	.92	2.81	6.36	10.03	11.48	8.04	8.92	10.97	8.86	8.58	3.17	83.83
Las Marias	900	2.22	.36	2.21	8.70	12.00	7.22	12.20	12.86	14.14	11.54	11.90	5.76	101.11
Mayaguez	75	2.62	.59	2.31	6.73	11.52	10.89	13.05	12.18	9.85	9.60	7.12	2.95	88.91
San German	197	2.81	.89	2.34	8.36	6.91	12.38	5.28	6.34	3.71	7.71	6.74	7.15	70.12

TABLE 2.—*Showing the average number of days on which 0.01 inch or more rain fell for each month and for the year at a number of stations in Porto Ri*

Station.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov	Dec.	Ye
North side.													
Adjuntas	13	7	12	12	19	19	19	19	19	20	17	13	
Arecibo	12	7	10	10	14	13	14	12	11	19	16	14	
Barros	10	5	8	6	19	8	11	14	11	16	11	10	
Bayamon	18	9	16	13	15	20	21	21	18	18	18	17	
Caguas	20	12	16	15	18	19	26	27	21	25	22	24	
Canovanas	23	9	15	12	12	20	26	21	19	19	20	22	
Cayey	17	11	13	11	13	20	17	16	12	14	17	18	
Cidra	8	7	9	7	11	14	14	13	10	9	11	14	
Corozal	10	4	8	10	14	12	17	13	8	13	14	11	
Isabela	10	3	6	9	13	12	11	10	10	13	13	14	
Isolina	14	7	13	15	19	19	18	19	19	19	17	15	
Manati	16	9	13	13	15	17	20	15	16	20	17	17	
Morovis	10	6	10	10	15	16	14	14	13	14	14	16	
Perla	23	14	18	19	21	25	26	21	22	24	23	23	
San Juan	17	8	16	13	16	20	22	19	18	19	19	18	
San Lorenzo	17	12	14	14	22	21	22	21	18	19	18	20	
San Salvador	14	8	14	10	19	15	17	19	19	22	15	15	
Utuado	10	3	5	9	14	10	11	12	11	14	12	8	
East side.													
Fajardo	15	6	13	11	14	21	21	16	14	18	19	15	
Humacao	14	6	18	11	19	21	22	18	18	17	16	12	
Maunabo	15	5	7	7	14	22	15	18	14	18	12	15	
South side.													
Aguirre	13	6	6	8	10	18	14	9	14	12	9	7	
Coamo	4	4	8	4	13	11	10	8	8	11	16	4	
Juana Diaz	7	1	7	8	12	13	9	11	8	15	10	8	
Ponce	7	2	4	4	10	9	9	7	6	13	4	5	
St. Isabel	6	5	6	7	11	12	10	12	9	10	8	9	
Yauco	9	3	6	7	9	11	11	8	9	12	8	8	
West side.													
Aguadilla	10	3	7	9	16	14	10	10	10	14	12	10	
Coloso	12	5	6	11	23	24	17	19	16	18	12	11	
Las Marias	7	3	6	10	19	16	21	16	15	14	13	10	
Mayaguez	9	4	6	11	17	19	21	18	16	18	14	11	
San German	10	3	9	11	10	10	12	12	10	14	14	10	

TABLE 3.—*Showing the monthly and annual mean temperatures (Fahrenheit) a number of stations in Porto Rico.*

[Means are based upon a five-year record.]

Station.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Yea
North side.													
Adjuntas	68.6	69.6	69.2	71.6	74.1	75.2	75.3	74.3	73.9	74.8	73.7	71.3	
Arecibo	73.3	73.4	73.8	76.1	78.4	78.2	79.0	79.3	79.5	76.4	76.5	74.1	
Bayamon	75.3	75.9	75.4	78.1	78.6	78.7	80.7	80.4	82.0	80.2	78.9	76.6	
Caguas	72.4	73.1	72.9	76.0	78.2	82.7	78.7	78.8	78.7	76.3	75.6	74.8	
Canóvanas	75.0	76.8	76.9	79.1	81.1	81.3	81.1	81.4	81.2	80.0	78.2	79.0	
Cayey	70.7	71.5	71.9	74.2	78.6	78.9	80.4	79.9	78.5	76.5	75.0	73.2	
Cidra	69.7	72.1	72.5	73.9	73.8	76.7	75.6	76.1	75.8	75.0	74.2	74.1	
Isabela	75.0	75.2	72.2	76.8	78.5	79.5	80.7	80.4	79.9	78.5	77.6	75.9	
Isolina	71.8	74.8	72.0	73.9	75.2	76.8	77.2	78.0	77.4	79.4	75.3	74.4	
Manati	75.6	75.5	75.0	76.4	78.4	79.3	80.2	81.7	80.4	79.5	77.7	75.4	
Morovis	73.7	73.3	72.6	76.0	77.8	78.6	78.7	79.4	78.6	77.2	76.9	73.2	
Perla	67.5	74.2	74.7	76.9	79.0	79.2	79.5	80.6	80.1	80.1	77.5	77.9	
San Juan	75.3	75.0	76.0	77.3	79.0	80.7	81.2	81.3	81.0	80.3	78.6	77.7	
San Lorenzo	74.0	74.3	73.9	76.4	78.5	78.9	76.8	79.2	79.6	78.7	77.1	74.1	
San Salvador	71.2	71.1	70.7	72.5	74.9	76.1	76.1	76.5	76.0	75.7	73.6	71.8	
Utuado	73.4	72.6	71.8	75.8	77.8	79.4	79.7	80.0	78.2	79.0	76.4	75.5	

LE 3.—*Showing the monthly and annual mean temperatures (Fahrenheit) at a number of stations in Porto Rico*—Continued.

Section.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
East side.													
rdo	76.9	77.4	77.0	79.0	80.7	80.5	81.6	82.6	80.9	80.3	78.9	77.0	79.4
acao	77.8	76.9	77.2	80.5	82.3	82.2	82.7	83.8	83.0	81.7	81.0	78.0	80.7
nabo	76.7	76.9	77.1	79.2	79.4	81.3	82.0	83.2	82.5	81.1	79.3	78.0	79.7
South side.													
rre	76.5	76.0	77.4	78.4	80.5	80.7	80.5	81.0	81.0	80.0	78.8	78.4	79.0
no	74.4	77.0	76.4	76.2	78.6	80.0	80.6	81.0	79.8	79.0	78.1	75.8	78.1
e	71.1	76.3	75.5	78.3	80.4	80.4	80.6	81.0	80.9	79.5	78.4	75.6	78.2
o	74.9	75.1	74.6	77.8	79.8	80.2	78.8	80.2	80.0	79.5	78.1	75.8	77.9
West side.													
o	73.9	73.9	73.2	76.4	78.6	79.1	79.0	79.7	79.2	78.2	77.0	75.0	76.9
guez	75.0	76.0	76.6	76.8	80.0	80.3	79.7	79.9	80.7	80.2	78.1	76.5	78.3

LE 4.—*Showing the extreme maximum temperature (Fahrenheit) for each onth and for the year during the five years 1898 to 1903, inclusive, at a num- r of stations in Porto Rico.*

Station.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Period.
North side.													
ntas	88	90	91	89	93	91	92	94	94	92	97	90	97
ibo	92	92	92	93	92	98	93	94	96	93	91	87	98
os	89	88	92	87	88	89	90	88	89	88	90	93	93
mon	93	96	97	97	96	97	97	97	97	98	95	94	98
as	89	89	90	99	97	95	93	94	92	92	95	92	99
vanas	85	91	91	95	97	95	91	95	95	92	89	86	97
y	96	97	96	97	95	98	99	98	100	96	98	94	100
	87	90	89	92	91	91	93	95	91	90	91	90	95
zal	91	93	94	96	96	93	95	94	94	92	93	92	96
la	87	94	89	96	91	94	92	93	94	93	89	89	96
a	86	91	90	91	91	93	96	92	93	91	89	89	96
ti	92	95	95	96	98	100	95	97	97	97	94	94	100
vis	92	90	93	95	95	98	95	97	95	95	94	89	98
	87	89	89	92	99	98	95	95	98	90	90	90	99
Juan	86	89	89	93	94	93	89	91	93	91	89	88	94
Lorenzo	90	92	93	93	95	92	92	96	94	93	92	92	96
Salvador	85	86	88	88	89	90	91	90	90	90	87	85	91
do	91	91	93	96	95	96	96	96	93	93	93	89	96
East side.													
rdo	89	92	91	93	93	93	93	95	96	96	92	89	96
acao	92	90	90	90	97	91	95	96	92	98	91	88	98
nabo	87	89	90	90	95	96	94	96	94	96	91	90	96
South side.													
rre	90	90	89	91	94	90	92	94	95	95	93	90	95
no	91	92	93	95	95	97	96	97	100	96	96	92	100
a Diaz	95	93	91	93	92	98	95	97	95	92	92	91	98
e	89	88	90	93	92	93	94	95	95	91	91	89	95
abel	87	89	90	92	93	92	92	96	96	94	92	89	96
o	90	98	98	96	95	94	96	99	99	93	93	91	99
West side.													
o	92	92	95	93	97	95	95	96	96	95	93	97	97
Marias	92	92	91	91	91	93	93	94	95	94	94	94	95
guez	91	92	94	97	97	96	96	97	94	95	93	92	97
German	91	89	90	93	97	95	96	100	97	96	96	95	100

TABLE 5.—*Showing the extreme minimum temperature (Fahrenheit) for each month and for the year during the five years 1898 to 1903, inclusive, at a number of stations in Porto Rico.*

Station.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	For the period.
North side.													
Adjuntas	48	48	44	51	51	55	53	52	52	53	50	53	44
Arecibo	59	58	54	60	67	68	65	65	65	60	60	54	54
Barros	51	50	51	51	48	56	60	61	55	52	55	51	48
Bayamon	55	57	56	60	56	60	60	60	60	60	60	56	55
Caguas	50	53	53	53	51	58	59	61	61	54	48	55	48
Canóvanas	61	62	65	66	67	72	72	72	71	70	68	63	61
Cayey	52	52	51	55	50	62	61	58	58	56	54	51	50
Cidra	50	51	50	53	50	54	50	53	57	50	54	51	50
Corozal	51	51	52	55	52	60	61	64	62	64	55	52	51
Isabela	60	60	59	62	65	68	68	65	64	60	62	62	59
Isolina	58	58	54	54	58	52	59	65	62	60	60	58	54
Manati	57	57	58	59	60	66	66	67	65	65	61	58	57
Morovis	56	57	56	60	57	62	64	65	61	62	63	56	56
Perla	61	61	62	63	60	67	70	71	65	62	68	63	60
San Juan	66	66	65	66	66	70	70	70	71	63	69	65	63
San Lorenzo	54	55	53	57	53	65	64	63	60	60	58	53	53
San Salvador	57	57	52	60	60	63	59	63	60	58	56	60	56
Utuado	56	50	50	52	56	63	63	63	62	61	51	56	50
East side.													
Fajardo	59	61	62	65	60	68	69	68	68	67	64	60	59
Humacao	54	58	60	61	65	64	64	66	64	64	62	60	54
Maunabo	63	62	59	65	66	69	69	69	67	66	65	62	59
South side.													
Aguirre	51	50	55	63	66	70	69	67	60	68	65	57	50
Coamo	58	58	56	60	57	60	64	60	60	60	60	55	55
Juana Diaz	55	52	58	62	60	67	65	68	60	67	65	63	52
Ponce	59	59	59	59	57	58	58	60	67	65	62	57	57
St. Isabel	62	62	58	62	61	70	66	69	68	66	62	61	58
Yauco	59	56	52	61	63	60	62	62	66	66	61	56	52
West side.													
Coloso	59	55	52	58	59	64	62	64	60	60	58	57	52
Las Marias	63	62	61	63	60	67	64	60	67	65	64	64	60
Mayaguez	59	56	59	60	63	66	65	58	63	62	62	61	56
San German	59	60	59	53	56	56	60	66	68	60	60	58	53

Professor ABBE. There is not very much to discuss in a paper like that on the climate of a place about which we know very little, but geographers are glad to get such descriptions of every State and every part of the world. At recent geographical conventions a number of papers of that kind have been read. I would like to commend the whole subject to our men for the preparation of such articles in order to disseminate a knowledge of climate and its relation to plants, trees, health, and other conditions.

Professor HENRY. Papers of this kind are always useful and welcome at the Central Office and will supplement a report now in preparation on the climatology of the United States. It would be well if all of those who are serving in the West Indies would prepare papers of a similar character.

MONTHLY STATEMENT OF AVERAGES FOR RURAL PRESS.

By Mr. W. S. BELDEN, *Vicksburg, Miss.*

It is believed that the usefulness of the Bureau can be somewhat extended in the more important agricultural sections of the country by the preparation of a monthly statement of averages for newspapers, similar to Form 1079, but based on data from all observation stations within a State. Data for such a purpose are now available at all section centers for a period of ten years or more.

It is of interest and value to many persons to know not only the average weather conditions over an agricultural State, or portion of an agricultural State, for an ensuing month, but also some of the temperature and precipitation extremes that have been experienced over the given area during the given month.

Weekly newspapers afford an exceptionally good medium for conveying this information to the public, for in many of the States there are more than a thousand weekly newspapers issued, a large per cent of which does not publish any Weather Bureau matter regularly. Weather information being an item of much concern to rural readers, especially during the growing season, the data at once become of sufficient value to warrant publication.

In some of the States the normal and extreme values could be given by districts as published in the monthly section reports.

In order to test the practicability of this plan the writer prepared the following statement of averages, which was issued to two newspaper unions the latter part of June, 1904:

U. S. DEPARTMENT OF AGRICULTURE,
Weather Bureau.

The following data, covering a period of sixteen years, have been compiled from the Weather Bureau records at 60 observation stations in Mississippi. They are issued to show the conditions that have prevailed in the State during the month in question for the above period of years, but must not be construed as a forecast of the weather conditions for the coming month.

MONTH OF JULY FOR SIXTEEN YEARS.

Temperature.—Mean or normal temperature, 81°.

The warmest month was that of 1901, with an average of 83°.

The coolest month was that of 1894, with an average of 79°.

Some of the highest temperatures recorded were as follows: 107° at Batesville and 105° at Greenville in 1901.

Some of the lowest temperatures recorded were as follows: 50° at Corinth in 1896 and 51° at Yazoo in 1903.

Precipitation.—Average for the month, 5.22 inches.

Average number of days with 0.01 inch or more, 9.

The greatest average monthly precipitation was 10.02 inches in 1892.

The least average monthly precipitation was 2.19 inches in 1896.

Some of the greatest monthly amounts of precipitation recorded were as follows: 23.87 inches at Macon in 1892 and 16.67 inches at Magnolia in 1900.

Some of the least monthly amounts of precipitation recorded were as follows: 0.13 inch at Hernando and 0.16 inch at Austin in 1896.

Clouds and weather.—Average number of clear days, 14; partly cloudy days, 11; cloudy days, 6.

Wind.—The prevailing winds have been from the southwest.

Issued at Vicksburg, Miss.

W. S. BELDEN,
Section Director, Weather Bureau.

The two newspaper unions printed the data in over 200 weekly newspapers in Mississippi. A statement of averages for August was issued the latter part of July, and in addition to sending the same to the two newspaper unions, each of which requested that such data be furnished regularly, all the daily papers in the State, except those at Vicksburg and Meridian, where Form 1079 is issued, were supplied with copies of the statement a few days later than the newspaper unions in order that the data might appear in both weekly and daily papers simultaneously. Nearly all the daily papers thus supplied printed the data and requested that similar data be furnished regularly. The distribution could be further extended to include weekly papers that do not use any matter furnished by newspaper unions.

During the fall and spring months frost data could be included in the statements and information relative to frequency and amount of snowfall could be given during the winter months. Possibly some other features might be mentioned occasionally. All data should be plainly and concisely stated.

There is reason to believe that the continued dissemination of information as outlined above would have an educational value in assisting to overcome superstitious beliefs in regard to weather causation, and when this is accomplished much will have been done to limit the field of operation of the so-called long-range forecaster.

DISCUSSION.

Mr. J. **Warren Smith**. Whenever I visit a voluntary station or go into a town on official business where a newspaper is published I inquire whether the long-range weather forecasts are being published. If they are, I take one of the long-range forecasts of recent date and a file of weather maps covering the same period and visit the manager of the paper. Fully half of the time I can convince him in a few moments of the inaccuracy of the forecast and the worthlessness of the matter to his readers.

I am constantly met with two arguments, however, that I can not answer. One is that newspapers in the large cities publish the forecasts, and the other, that the Weather Bureau does not furnish anything to take the place of the long-range forecasts.

With a Weather Bureau office in practically all of our large cities, and with the opportunities that the officials of the Bureau have to get acquainted with the editors and control to great extent the weather matter that is published, the first argument ought not to be true.

The second argument, if from the manager of a daily paper, can be met to a partial extent; but if from the manager of a weekly paper, it is unanswerable. Talk to him as much as we will, and he still says, " The public wants something of this kind; the Bureau does not furnish it and these long-range fellows do."

For this reason I wish to recommend and urge that instead of a monthly statement of averages for the rural press we issue a weekly statement.

This statement should be mailed on Monday evening. It should contain—

First. A statement of the conditions prevailing over the country on Monday; the probable movements of the areas then shown, with the attendant weather for Tuesday and Wednesday, if the areas are well defined; their expected and possible movement if poorly defined; an outline of what may be expected on Thursday if certain conditions obtain, or what may be expected if certain other conditions are controlling, and the plain statement that no one by any possible means can predict the weather for Friday, Saturday, Sunday, and Monday.

Second. With this, and appropriate to the season or areas prevailing, should be given a brief, plain statement or description of lows, of highs, of thunder and hail storms, tornadoes, cold waves, West

Indian hurricanes, storm tracks, winds, correlation of wind and pressure, wind and temperature, hot spells, cold winters, cool summers, etc.

Third. Whatever actual figures that may be available and appropriate to the season: Average date of frosts, earliest and latest frosts, highest and lowest temperatures, heavy rainfalls, heavy snows, dates of snowfall, etc.

The first part of the article must be written by the officials themselves, and the ability of an official to handle the matter can be easily determined by having weekly statements sent to the Central Office for a few weeks before beginning publication.

The second part should be written at the Central Office, for the first year at least, and sent in advance to the different officials.

The third part should be compiled from station or section data as opportunity offers.

I thoroughly believe that by this method the Bureau can open a campaign of education that can be accomplished in no other way, and can do more to dispel ignorance of the laws of the atmosphere, break up superstitious ideas, and show up the real character of the long-range forecast fakes than can be done by years of occasional newspaper articles and the publication of elaborate and exhaustive theses in scientific reports.

Mr. JENNINGS. In regard to Mr. Belden's paper, I think he would improve it a little by dividing the State into two or three divisions. It is a pretty long State and runs down to the Gulf. If instead of including the whole State in one statement of averages he had divided it into two or three sections he would have improved it considerably. We do not give the clear, cloudy, and rainy days—that is, the average—for a number of years, but we do give the mean temperature for each division and for the State, the highest and lowest temperatures, and the average, greatest and least precipitation, during seventeen years. In other words, we have a table running in the bulletin that covers pretty fairly the field that Mr. Belden mentions.

Professor ABBE. I think this idea of Mr. Belden and Mr. Smith can certainly be worked out and made very useful. We could state weekly and monthly what has happened in the past week and month and then say what will happen in the next two or three days, then say we can do no more forecasting, but that, judging from past records, the total number of rainy days will be so many, of frost so many, etc., based on records of past years. That is precisely what the Hydrographic Office is doing every month in its pilot chart. It gives us a chance to show the people that we know something about what is likely to happen next month.

Professor MOORE. That very matter was discussed with the Board on Wireless Telegraphy that recently met in Washington, and as a result Admiral Manney changed the word " forecast " to " averages." I am not at all favorable to the attempt to forecast on averages, for it is a fact that the normal is a thing that seldom occurs. The normal is a mean between two extremes and there is nearly always some departure from that normal, and when you get a normal day or a normal month everybody is surprised. The normal is the thing they do not get. Therefore, any forecast based upon a normal—upon average conditions—is going to bring discredit upon the Service. It will not be a forecast.

Doctor **Fassig**. In reference to the last statement of our Chief, as to the occurrence of the normal, it may interest you to know that in Baltimore out of 87 winters a normal did not occur within one-tenth of a degree a single time.

Professor **Henry**. The idea suggested by Mr. Belden is an excellent one and if fully developed may give a very effective means of putting the long-range forecaster out of business. The principal thing is to write up the summary for the State in narrative form, avoiding statistics as much as possible, and make an article which will take with the ordinary newspaper reader. I think the matter ought to be looked into.

IRREGULARITIES IN FROST AND TEMPERATURE IN NEIGHBORING LOCALITIES.

By Dr. I. M. Cline, *New Orleans, La.*

In localities where the Weather Bureau forecasts and warnings are used extensively as a guidance in preparing protective measures for growing crops, attention has been specially directed to the effects of weather conditions on the crops protected. The protection of the cranberry crop in Wisconsin,[a] and the protection of fruits in California,[b] all show that the use of warnings has developed a closer study of the effects of weather on growing crops.

The extensive and successful use of the warnings in the protection of sugar and trucking interests along the Gulf coast during recent years has resulted in directing attention to the occurrence of frost and temperature conditions that are not explained by air drainage. These conditions apparently fall under two heads:

First. The temperature varies greatly in different localities in immediate neighborhoods. The temperature at regular Weather Bureau stations is often very different from that which prevails in the neighboring agricultural communities. In this connection Mr. H. Meyer, under date of Bertrandville, La., November 23, 1901, says:

> There is considerable trucking done here in the early spring, and I hope you will give us warning when a cold wave comes along. What I can not understand is, that the 16th of this month your record (New Orleans) was 44°, while at this place, 25 miles farther south, we had 32°. Ice formed as thick as window glass.

In this case we find a difference of 12° in the temperature recorded at the Weather Bureau station and that recorded 25 miles farther south, in the truck-growing district. It was barely cold enough for light frost at the Weather Bureau station, but a killing frost occurred in the neighboring truck-growing community.

Hon. Henry McCall, collector of customs, New Orleans, La., under date of McCall, La., November 11, 1903, says:

> There is a difference in the minimum temperature between the readings on the custom-house at New Orleans as compared with the temperature in the country adjacent to New Orleans. We often find a difference of 10° or 15° between the minimum, say, at McCall (near Donaldsonville) and that recorded

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[a] Paper by Prof. Willis L. Moore, American Meteorological Journal, Vol. X, No. 2, pp. 89 et seq.

[b] Bull. 23, Weather Bureau, by W. H. Hammon, and Bull. 29, Weather Bureau, *by Prof.* Alexander G. McAdie.

s the minimum reading at New Orleans. Last week, I think it was Satur-ay morning, the 8th instant, the minimum was 35° at McCall and 49° at New rleans.

Such differences in temperature as those noted above are of frequent occurrence. During the winter, when a crest of high pressure is central over Arkansas, northern Louisiana, and northeastern Texas, a slight rise in temperature frequently takes place at Galveston, while the temperature falls 4° to 6° in the sugar region, 0 to 100 miles to the northwest of Galveston and in the rear of the anticyclonic area. This has been frequently noticed, especially when the weather remains clear. During cloudy weather such differences in temperature do not occur.

A comparison of the minimum temperatures recorded at the United States Weather Bureau office, St. Louis, Mo., with those recorded at the Forest Park Observatory[a] shows that the mean monthly minimum at Forest Park was 1.5° to 9° below the mean monthly minimum at the Weather Bureau station. In the discussion of this matter the writers say:

> In the study of these observations it was found that during the clear skies of September the maximum differences were recorded, while during the cloudiest months (March and December) the differences were least and that they remained small during all the winter months. There were, however, marked exceptions to this rule, as, for instance, in January, 1892, when the difference exceeded 20° on three successive dates.

In looking for the causes of these differences in temperature, the conditions which favor or retard radiation must be considered. The differences in temperature in the cases cited appear to result from differences between the amount of heat lost as a result of radiation in the city and in the country. In the city the atmosphere is filled with dust motes to a greater extent than in the country. Mr. John Aitken has counted the visible dust motes in samples of air.[b] He found a great difference between the number of dust motes in the samples of air from cities and those from the country. In large cities there were hundreds of thousands of motes in one cubic centimeter of air, while there were thousands in the same quantity of air from small towns, and only hundreds in the sample taken from the open country. The large number of dust motes in the atmosphere of the city retain the heat received by the earth and the lower atmosphere. In the country, the number of dust particles being comparatively few, a larger proportion of the heat received by the earth during the day is radiated at night and allowed to pass through the lower atmosphere into space, thereby reducing the temperature of the earth and adjacent atmosphere to a lower degree in the country than in the city.[c]

In connection with this subject Mill says:

> After sunset the hot land radiates its heat through the atmosphere and falls to a low temperature, thereby chilling the air in contact with it, and were it not for the dust motes and condensed water catching and retaining the most of this heat the radiation of a single clear night would chill down the land far more than the solar energy received during the day could heat it up. (The Realm of Nature, p. 109.)

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[a] U. S. Monthly Weather Review, January, 1902, pp. 12 and 13.

[b] On the number of dust particles in the atmosphere, Trans. Royal Soc., Edinburgh, XXXV, p. 1, 1888.

[c] Davis' Meteorology, pp. 7, 8, 26, 27, and 159.

The absolute amount of water vapor in the atmosphere is a matter which requires consideration, because water vapor in its condensed form is one of the chief agents in retaining heat in the earth's atmosphere.[a]

The condensation of the water vapor in the atmosphere is hastened by the presence of dust particles, and consequently the tendency to condensation with cooling at night is greater in the city than in the country under the same general pressure conditions.[b]

A careful study of the foregoing, in connection with the authorities cited, leads to the conclusion that the difference between the number of dust particles in the atmosphere over the city and the number over the country and their influence on radiation form the basis for the explanation of the occurrence of lower temperatures in the country than in adjacent cities. The greatest differences in temperature occur in clear weather, when the influences of the dust particles would be greatest.

Second. In fields of growing crops it is not uncommon to find, after the occurrence of frost or injurious temperatures, small areas scattered over the fields where crops have suffered much greater damage than in other parts of the same field; in some instances this condition covers the greater part of a field. This feature is noticed frequently in connection with the tender classes of vegetation grown by truck farmers, and it also occurs to a marked extent and on a large scale in the hardy and extensively cultivated crop of sugar cane.

In this connection Mr. Mills Malinot, manager of a sugar plantation at Avoca, La., wrote this office under date of November 17, 1901, as follows:

> If not asking too much of you, will you kindly inform us why sugar cane and other forms of vegetation suffer most on black land when there is a freeze?

Mr. J. E. Burguieses, secretary of the Oak Lawn Sugar Company, Oak Lawn, La., states under date of February 27, 1903:

> The canes on black, stiff land are more susceptible to frost than those on sandy land.

It does not appear necessary to cite other records, as conditions similar to the foregoing have been found to exist generally throughout the sugar and trucking regions.[c]

In connection with these features Storer[d] says:

> It is true, however, after fully allowing for the climate of a locality, that the temperature of the soil of any particular field may be subject to a great variety of circumstances. It will be influenced not only by the quantity, quality, and direction of the sun's rays which fall upon it, but by the temperature and amount of the air, the rain, and ground water which come in contact with it, by the amount of heat developed within it through oxidization of the organic or other oxidizable substances which it contains, by loss of heat through evaporation of water, by the capacity of the soil itself for absorbing and retaining or for radiating and reflecting heat, and doubtless by other conditions, such, for example, as those dependent upon the presence or absence of vegetation and of microscopic organisms.

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[a] Davis' Meteorology, p. 145.

[b] Davis' Meteorology, p. 163.

[c] U. S. Monthly Weather Review, 1902, Vol. XXX, p. 479.

[d] Agriculture, vol. 1, p. 45.

It has been found in laboratory experiments that the temperature f a white-clay soil rose to 106° when exposed to sunshine in air of 7°, while on blackening the clay its temperature rose to 120°,[a] a rise f 14° as a result of the difference in the absorptive powers for heat f the different colored soils. Of course we do not expect to find this xtreme condition in nature, but we do find soils that show such dif-erences in temperature over them that the attention of even a casual bserver is attracted thereby. According to Deschanel[b] a perfect adiator would be a substance whose surface offered no resistance to he passage of radiated heat in either direction. Such being the ase, a soil which absorbs heat rapidly and becomes warm during the ay radiates heat rapidly and becomes cold at night when the source f heat is removed, while a soil which absorbs heat less rapidly during he day cools with less rapidity at night. Dark soils approach more early the perfect radiator than the lighter soils, and from the fore-oing we may expect to find the night minimum temperature at the urface of a black soil 6° to 14° below that of a light soil during the assage of a cold wave, when conditions are favorable to excessive adiation.

The character and color of soil on which crops are grown certainly ave much to do with the occurrence of frost and injurious tempera-ures, and apparently explain the "frost patches" which are not xplained by air drainage.

DISCUSSION.

Mr. **MITCHELL**. I think that the effect of frost is largely due to the mount of fertilizer used, character of fertilizer, and the condition f the plant. In Florida experience has shown that growers should e very careful as to the time of fertilizing the groves. If it is done oo late the plant is tender, winter catches it in its tender condi-ion, and therefore care must be exercised in applying fertilizer. It ught to be done well before or immediately after the frost period. think the forecaster in Washington always takes into consideration he probable temperature near the surface of the earth; in other words, the difference in temperature that prevails at the station and t the surface of the earth.

Mr. **SEELEY**. I made a few observations on the temperature of the soil at the surface of the ground, and I found there was a marked difference within short areas. In regard to soils, the temperature varies a great deal with the color of the soil, as Doctor Cline has said, but another important point is the compactness of the soil. Cultivation greatly affects the radiating power, and the chemical composition also has a great deal to do with the temperature that is retained. But what has struck me most in making these observa-tions is the great difference between the radiation from surfaces cov-ered with vegetation and that from bare ground. I think I noticed a difference of over 10° in one case. The ground was simply covered with grass, and on another plat of the same soil uncovered the dif-ference was over 10°.

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[a] Storer, Agriculture, vol. 1, p. 52.

[b] Natural Philosophy, p. 438, par. 471.

FORMER CONVENTIONS OF WEATHER BUREAU OFFICIALS.

By Mr. James Berry, *Washington, D. C.*

It having been suggested that a few notes relating to former Weather Bureau conventions might prove of sufficient interest to justify their presentation to this meeting, the following summary has been prepared. Doubtless the suggestion referred to was prompted by the fact that the speaker has participated in an unimportant way in nearly all of the previous conventions, his connection therewith having begun in 1893 as secretary of the American Association of State Weather Services.

Prior to the organization in 1892 of the association just named there had been but one convention of this character under the auspices of the Government Weather Service, so far as the speaker is aware, and that was held at the Smithsonian Institution in Washington, February 24 and 25, 1886. The gathering at that time was noted for the men of eminence constituting its members, among whom were Abbe, Ferrel, Mendenhall, Davis, Rotch, Upton, and others. There were also present the head of the Government Weather Service, Gen. W. B. Hazen, and a number of his leading assistants, some of whom, still connected with the Government Weather Service, are present at this meeting. State weather service organizations were represented at the Smithsonian meeting as follows: Alabama, by Prof. P. H. Mell, Agricultural and Mechanical College, Auburn; Indiana, by Prof. H. A. Huston, Purdue University, Lafayette; Minnesota, by Prof. W. W. Payne, Carleton College, Northfield; New York, by Prof E. A. Fuertes, Cornell University, Ithaca, and Ohio, by Prof. B. H. Thomas, Ohio State Board of Agriculture.

The American Association of State Weather Services continued nominally as an affiliated society of the American Association for the Advancement of Science from its organization until 1895, and during this period met annually, first in Rochester, and subsequently in Chicago, Brooklyn, and Indianapolis, in the order mentioned. Only two of these meetings, however, viz, those held at Rochester and Brooklyn, were in conjunction with the American Association for the Advancement of Science, as it was found impracticable always to meet with that association, which sometimes gathered at places outside of the United States, a centrally located city being almost indispensable to secure full attendance of Weather Bureau officials.

When the present Chief was called to the head of the Bureau in 1895 he decided, after the Indianapolis meeting of that year, that subsequent conventions should be composed of officials representing without restriction all lines of work conducted by the Bureau, and furthermore, that the interval between the conventions should be lengthened to three years. There was therefore no convention between the last meeting of the American Association of State Weather Services at Indianapolis in 1895 and the First Convention of Weather Bureau Officials in Omaha in 1898. Since 1895 triennial conventions have been the rule.

The proceedings of the early conventions show how earnestly those who composed their membership were striving to build up the service, and also how clear and well defined were their conceptions of the lines of work promising the best returns. How to do and where to obtain the means for doing so much that they saw was desirable to be done were the absorbing questions. To-day it may be said that many, if not most, of the important problems of those days, simple as they may now seem, have been successfully solved.

With larger and more important ends in view the efforts of these irst conventions were necessarily directed to clearing the ground and paving the way, and not a few of the improved methods of work now n vogue are largely the outcome of plans that were discussed and developed on those occasions. As examples of this class, in which he pioneer labors of these conventions were concerned, attention may be drawn to the striking growth of the voluntary observation ystem of the Bureau and to the improvements that have been brought bout in the methods of publishing the monthly reports. In the early period of the climatological service of the Weather Bureau there were fficials connected with the Government Weather Service who thought nd ruled that there were insurmountable legal obstacles in the way of lending a few inexpensive instruments, such as constitute the voluntary observer's outfit to an observer willing to take observaions every day in the year and to furnish records thereof. The radical change in policy that has taken place since then is evidenced by the fact that there are now more than 3,300 voluntary observers, whose stations are equipped with properly exposed instruments of standard pattern, tested by the Weather Bureau for accuracy before issue. The monthly reports of the State weather service organizations up to 1895 were isued in a variety of forms and sizes, some by duplicating processes, and others printed. None of the printed reports were issued at the expense of the National Weather Service prior to 1895. In some cases the cost was defrayed by funds appropriated by State legislatures, in others by revenues derived from advertisements, and in others the reports were published at the expense of educational institutions with which the National Weather Service was in cooperation. After 1895 these gave place to the standard form of publication adopted for every State. To illustrate the advance in the matter of issuing these publications, I will exhibit two volumes, one containing the reports of a State organization prior to 1895, the other being a file of monthly reports of a climate and crop section for a later year. Thus the questions of how to provide means for procuring instruments for observers, flags for displaymen, printing of bulletins, inspections of stations, and other matters of a imilar character, no longer engage the main attention of Weather Bureau conventions. As these were gradually dealt with they became matters of mere routine, and questions of greater pith and moment have taken their place.

With a view to securing opinions of representative officials regardng the beneficial results of the Milwaukee convention held three years ago, I recently wrote to a few men whose positions gave them xceptional opportunities for observing the effects of that meeting. Their expressions, which follow, are in one particular strikingly simiar, when it is considered that their fields of duty are widely sepaated and that their statements are based on personal conviction, ven though these may afterwards be found to represent a collective hought. They all agree that valuable as the papers and their formal discussion may have been, the greatest benefit was that resulting from the informal intercourse afforded by the coming together of the Bureau's officials. The reply made by Professor McAdie, of San Francisco, is so complete as to leave little else to be said. He communicated with the officials in charge of a number of stations and gives the following résumé of the result:

> An expression of opinion from 40 station officials who attended the last convention brings out some instructive facts concerning both the immediate and the after effects of the meeting. Although three years have elapsed, 36 of these men write enthusiastically of the Milwaukee assemblage. First and foremost is an expression of appreciative regard for their fellows. Possibly every man present put his best foot forward and was on his mettle, realizing that his neighbor, expecting the best, was in turn giving the best that in him lay. Be this as it may, one is struck by the prominence given to the personal-influence factor. The convention worked as a unit. There was a striking absence of any endeavor for individual recognition. No man seemed to be working for himself alone. At least twenty statements might be quoted to show how widespread and deep was this impression of united effort and personal broadening and benefit. One example will do for all. After mentioning his belief that a good way to make men good is to put them in touch with good men, one of the oldest men in the Service continued: "I left that convention with increased respect and esteem for the members of the Bureau, individually and collectively." It is also not to be forgotten that the Chief of the Bureau, as chairman, made a significant remark just preceding adjournment: "Not a man has said a word against another."
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> Coming now to the very practical question of innovations, reforms, and improvements accomplished either directly or indirectly by the convention, it is noted that a number of the suggestions made have been followed up. Suggestions were: First, in the line of bettering our instrumental outfit, and the matters especially considered were maximum and minimum thermometers, instruments and exposures, and rain recorders, especially for light precipitation, showing the times of beginning and ending, and, what is equally important, the character of the precipitation. Other suggestions bore on river gages, storm-warning displays, lightning recorder, etc. The second class of suggestions dealt with improvements in forecasts, chiefly with the method of presentation to the public, and, secondly, with verifying systems. A paper which seems to have been most marked in its influence, if we can judge by the frequent reference made to it, was that of one of our guests, criticizing certain practices in connection with the forecasts for Washington, Baltimore, Philadelphia, and New York, and also pointing out from the standpoint of a newspaper man certain practices which he thought might be advantageous for us to follow. It is noted that some of the suggestions still remain unacted on, but that the paper struck home is evident from the statements of a number who have studied it and profited by it. One can realize how earnest the convention was in its discussion of forecasting by the range of subjects, which included forecast telegrams, general and local forecasts, forecasts and the press, forecasts and the public, verifications, double observations, aids in forecasting, labor-saving devices, etc.
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> The third line of discussion at the convention was in connection with the progress of meteorology. Lectures in schools, colleges, before farmers' institutes, and other bodies were discussed. Research work, original investigation, the establishment of observations, received attention, and perhaps the present convention will witness the realization of some of the plans proposed at the earlier convention.
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> The fourth important issue raised at the Milwaukee convention was that of preserving, simplifying, and improving records and meteorological forms. This seems to have borne fruit, and we shall doubtless hear much thereof at this convention.
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> The other great issue was in connection with climate and crop work. Many suggestions made by various directors have been tentatively put into operation. It may be noted in passing that climate and crop work requires more or less familiarity with methods used at other stations, and while nothing can take the place of a personal inspection of the workings of some well-conducted section, probably the next best thing is the opportunity of asking information on

ittle matters and exchanging views as to the feasibility of this or that method of operation.

Summing up the opinions of 40 station representatives, we find that a number of them have followed up both the suggestions which they themselves made at the convention and the suggestions which were made by others. Again, while a number of men state that they have not as yet acted on certain suggestions, they have not forgotten them and intend at a later date to put them nto operation. Many made notes concerning improved methods of work and where practicable have adopted the new methods.

The use made of the bulletin reporting the proceedings of the convention is especially interesting. Some few men say they made no use of it, which seems almost beyond comprehension, and probably does not truly represent the facts. Quite a number say that they made no special use of the bulletin, though they read many of the articles with decided interest, and they have frequently referred to some of the papers for certain data and information. More than half say they have used it quite extensively for reference. Some have used it for lecture purposes and some for giving information to the press. In some sections copies of the bulletin were widely distributed and in other sections there seem to have been but a few copies available. Several men refer o their personal copy as having been loaned a number of times. Three or four members have read carefully the entire bulletin from beginning to end. Some of the articles have been reread a number of times. In a few offices extracts have been made for office use. Again, in a few offices the bulletin has been discussed by the entire office force.

In one office the following words of the Secretary, found on page 238, have been cut out and posted in the most conspicuous place in the office:

" I need not attempt to flatter you, because Mr. Moore has been doing that, but I must say that I have looked in the faces of some bodies of gentlemen in my time, and I think this pleases me as much as any I have ever met. I may as well admit here in your presence that I am more exacting regarding your conduct than I am regarding the conduct of any other bureau in the Department. Anything done by a Weather Bureau man that tends to interfere with safety and progress can not be overlooked or forgiven. We may give a second chance to the man who steps aside in other bureaus, but the policy regarding you is remorseless, because the lives of our people and the property of our people are in your keeping, and you must be, as you are to-day, gentlemen of education and character. But I want to say, on the other side, that, being so exacting with the men of the Weather Bureau, I am anxious at all times for the advancement of the Bureau and the advancement of each of you connected with it. Nothing gives me more pleasure than to be able to do something to gratify a Weather Bureau man."

Dr. W. M. Wilson, in charge of the Weather Bureau office at Milwaukee, whose efforts contributed so much to the success of the convention held there, states:

It is an extremely difficult matter to state specifically wherein the station official is most benefited by the conventions. It is very much like trying to name those particular things one learned at school that contributed to success in after life. To my mind, the benefit of these meetings, especially to station officials, lies partly in their broadening, educational character, but mostly in the inspiration and enthusiasm for the work which one necessarily imbibes. The value of the conventions is by no means contained in the published reports of formal discussions and more formal papers. The real test is, What do we carry away that shows in our work? It is certainly not the scientific thesis nor the painful efforts of good observers at writing poor papers. It is the inspiration, the enthusiasm, the fire. I am aware that this is intangible and would make a rather poor argument before a Congressional committee, but for myself it has been that which most benefited me; getting to know each other better and to understand the enormous work being done throughout the country, broadening our views, and giving new things to think about.

The following is the opinion of Dr. O. L. Fassig, in charge of the Weather Bureau office at Baltimore:

While my personal experience in connection with the Weather Bureau conventions is limited to the Milwaukee convention, I have taken part in many other gatherings of a similar character, both in this country and abroad. While the subject-matter discussed and the stimulative value of papers presented have varied greatly, the most important benefits, I firmly believe, of all conventions are the incidental results of a better personal acquaintance and the informal interchange of ideas between those who are working along similar lines. The new ideas thus gathered and the personal word of appreciation which comes from your colleagues are more potent incentives to further effort than the benefits derived from the formally presented paper. The instruction and stimulus afforded by papers may be obtained from the printed report. Great as the benefits of the formal and intellectual features of the convention may be, the indirect benefits referred to are greater, or the convention fails of accomplishing one of its chief purposes.

Mr. J. Warren Smith, in charge of the Weather Bureau office at Columbus, Ohio, gives his views in the following statement:

> I should place, first, the value of personal contact with the Bureau officials, both from Washington and from other stations; the knowledge of what others are doing and how they are accomplishing it; the feeling that one is only a part of a great body, the successful work of which depends on his efforts, and perhaps more than all, the enthusiasm generated by what we see and hear. This was particularly true of the Milwaukee convention. The words of the Chief, the words of the Secretary, and the words of those outside of the Bureau, particularly from Snow and Watts, simply filled me to the brim with enthusiasm in my work and appreciation of it as well. I haven't gotten over it yet, and believe that it is affecting my work to this day. Not only this, but it has helped me to know my place—i. e., in work outside of the regular routine—the convention aided me to see the special lines that should be taken up and how my ability and training for taking them up compare with others.
>
> Secondly, the papers and discussions help to systematize and unify our station work; we can take advantage of the plans of others that are better than ours; we learn that we are not the only ones who have problems to solve, and that our station is not the only one with hard work. Then the reports of the conventions are valuable station text-books, as we use the ideas presented for reference and aid. My impression is that fewer papers and more time for discussion would be better. The conventions certainly incite efforts to prepare papers that would not otherwise be prepared, as well as bring out valuable points and ideas in discussion. Of course all this means more effective work on the part of the station officials, and hence makes the Service of more direct benefit to the public. From the standpoint of a station official I feel that the conventions are of benefit generally, for this reason, the central-office officials get some ideas and suggestions which are finally worked out for the benefit of the public, but more than all the Chief and others learn the ability, the talent, and the energy and characteristics of the men in a way that can not be learned from written reports and records and routine station work. The result is that the most effective men are pushed to the front, with benefit to the Bureau and to the public.

The 5,000 copies of the Milwaukee convention report were given a very judicious and economical distribution, but the demand for it was such that the edition was nearly exhausted within a few months after it appeared. It was sent to all of the leading educational institutions in this country and to many abroad, and nothing but favorable comment thereon has been made, so far as I am informed. Mr. Robert DeC. Ward, Harvard University, in a recent communication replying to an invitation to attend this convention, wrote:

> May I take this occasion to say that the proceedings of these conventions always interest me greatly; that I read the published reports on them carefully, and that I have more than once called attention to the importance of these gatherings in my notes on meteorology published in Science and elsewhere.

Believing that my fellow-workers in the Bureau will feel the same pride that I experienced upon learning how highly our efforts at the Milwaukee convention were appreciated by one of the foremost scientists in the world, I have obtained the privilege of quoting the following letter from Dr. Julius Hann:

VIENNA, *July 24, 1903.*

Prof. CLEVELAND ABBE, *Washington, D. C.*

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I have just employed my vacation leisure in reading the proceedings of the second convention of Weather Bureau officials, Milwaukee, through, and I must tell you that it has interested me in the highest degree from a twofold point of view. In the first place I have learned a great deal from several of the communications, and have read them with great interest. In a new edition of my Handbook of Climatology I shall often have occasion to make use of these communications. In the second place I have perceived to what a high state of perfection the weather forecasts of the United States have attained; what learned careful men with original ideas the Weather Bureau has at its disposal. I have also received a great impression of the great financial benefit that the United States derives from its Weather Bureau, and also of the profit that will accrue to meteorology as a science from exertions. I congratulate Professor Moore and yourself upon these results. You are, if I mistake not, the only man who has been uninterruptedly associated with this work ever since the establishment of the weather service in 1870.

* * * * * * *

I beg that you will present my respectful greeting to Professor Moore, and with highest regard, I remain,

Very respectfully, J. HANN.

Each convention so far held has excelled in importance and achievements the one immediately preceding, and I am confident that the belief is well founded that the Peoria convention will not be an exception to this rule.

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